VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
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VEKTOROVÁ OPTIMALIZACE VĚDECKÝCH PARKŮ ZALOŽENÁ NA KVALITATIVNÍCH/TRENDOVÝCH MODELECH BEZ ROVNIC

MULTI-OBJECTIVE OPTIMIZATION OF SCIENCE PARKS BASED ON QUALITATIVE EQUATIONLESS RELATIONS

DIZERTAČNÍ PRÁCE
DOCTORAL THESIS

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BRNO 2011

Abstract

The dissertation deals with the Multi-Objective optimization of the Science parks in terms of increasing competitiveness of the regions and the whole country. The main target of this dissertation is to help the investors, who want to implement SP project in different regions of Czech Republic or managers of existing science parks, who want to make another decision. This applies to all regions in Czech Republic, including regions, that were previously able to rely on availability and exploitation of mineral resources (traditional coal mining), which previously functioned as an important factor for industrial development and economic activity. Nowadays those regions must cope with the loss of competitiveness and to move their efforts into research and development and produce innovations.

Qualitative modelling is suitable for such poorly known and complex systems as SPs. SP models incorporate variables of different nature and different time behaviours. Therefore slow and fast SP models are studied. A set of 17 slow qualitative equationless relations, among 11 slow variables (e.g. Quality of R&D engineers, Competition status ect.) together with a set of 14 fast qualitative equationless relations, among 10 fast variables (e.g.Cooperation between industries and academics, incentives for investment ect.) is studied. The model's solutions i.e. set of slow and fast scenarios and transitions among them, are presented in this disertation in full details.

Analysis/Optimization of ill-known, nonlinear, multidimensional system as Science Park (SP) is a difficult task and it is difficult to develop meaningful and sufficiently accurate models of any unsteady state SP behaviours. A systematic analysis of a sequence of qualitative solutions is the key part of the dissertation and its main scientific contribution. The individual steps of production of the models are graphically illustrated in the examples. The dissertation includes interpretation of the results and benefits for the theory and practice.

Keywords

Science park, qualitative models, equationless relations, scenarios, transition graphs.

Bibliographic citation of dissertation

WOUTERS, H. *Multi-Objective Optimization of science parks based on Qualitative Equationless Relations.* Dissertation thesis. Brno: University of technology, Faculty of business and management, 2011. 158 p. supervizor Prof. Ing. Mirko Dohnal, DrSc.

Declaration

I declare that the PhD dissertation thesis entitled "Multi-Objective Optimization ofscience parks based on Qualitative Equationless Relations" I have developed independently under the leadership of Prof. Ing. Mirko Dohnal, DrSc. and using professional literature and other resources that are all properly cited in the work and listed in the bibliography at the end of this dissertation thesis.

As the author of the thesis I further declare that in connection with the creation of this dissertation, I did not infringe the copyright (in accordance with Act No. 121/2000 Coll. The copyright and rights related to copyright).

In Nehvizdy day

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Ing. Hana Wouters

Acknowledgments

I would like to thank my supervizor Prof. Ing. Mirko Dohnal, DrSc. for professional mentoring of this thesis, providing software, useful advices and comments and support, which helped me to develope this work.

I would also like to thank to all my family, my husband, my friends and my colleagues for moral support and motivation to complete this work.

I can not forget to thank to my supervisor – head of methodological department of the Regional Council Central Bohemia Ing. Jiří Kubiš for patience and nice behaviour at work.

Obsah:

1. Introduction

Confrontation with the needs of adaptation to the global challenges take place in a situation, where the economic level between the different regions in European Union remain significantly different. Many regions in several Member States do not fully exploit the portunities of the Single Internal Market and other projects of European integration.

Moreover, the effects of the recent economic crisis changed the position of the regions as well. Regions of Czech Republic are ranging between 62 -74% of EU average GDP (with exception of Prague) and look much more compact in comparison with the regions at EU level. They are therefore still largely underdeveloped, but on the other hand, they are already far enough from the very poor regions (50% below the EU average). [63]

Competitiveness of Czech economy is declining, competition in markets where ourproducts or services compete, grow.

A recent change of competitive position of CR is due to a gradual loss of price competitiveness and slow shift toward more sophisticated production, which would allow to compensate this change in terms of impact on the position of the economy.

In terms of social cohesion is necessary to prevent future decline in competitive advantage of Czech Republic by emphasis on quality, not dominantly on the cost of production (especially with the impact on the ability of economy to create jobs in this development) and to utilize the benefit from this process for the economy - what is a cost from the perspective of companies is the wage for Czech citizens and thus the main source of their wealth.

From the perspective of integration of Czech Republic into the global economy is necessary to rely less on extensive nature of the economy – the development driven by (especially foreign) investment - and conversaly to strengthen the intensive growth associated with effective use of intangible assets (knowledge, skills and innovative potential) as a key source of competitive advantage.

It is necessary to improve the quality and relevance of education at all its stages, to set motivating activity policy at the labor market and link them with the education system of lifelong learning. To strengthen the innovative development of the nation it is necessary to increase the efficiency of cooperation between industries and academics, including greater involvement of enterprises in research (even in foreign technology-oriented companies operating in CR, using research capacity outside our country). [102]

Not all regions, however, may take this way and in therms of Czech Republic may not seek to build centers of excellence in each region. Experience shows, that innovation can be implemented in regions without significant potential in high-tech industries. Innovation can be created in traditional sectors such as agriculture or traditional industries.

At nowadays EU level are three main instruments to support innovation activities. The first is the Cohesion policy (i.e. the Structural Funds (SF) and Cohesion Fund), the second is 7 Research Framework Programme (FP7) and the third is the Framework Programme for Competitiveness and Innovation Programme (CIP). [101]

To implement the Strategy for the development of small and medium enterprises for 2007-2013 is allocated in total 3.578.014.760 €, of which 3.041.312.546 € is the EU community contribution and 536.702.214 € is the contribution from national public resources. [91] [108]

To Enhance growth and competitiveness of the state and focus on knowledge based economy for the period 2007-2013 is allocated 2.436.095.160 € of which 2.070.680.884 € is the EU community contribution and 365.414.276 € is the contribution from national public resources CR. [96]

The implementation of educational development in order to strengthen the competitiveness of CR through modernization of initial, tertiary and further education, their interconnection into a comprehensive system of lifelong learning and improving conditions in research and development for 2007-2013 is allocated 2151.4 million €, while contribution of EU community is 1.828.7 million €, and national public resources from the state budget is the remaining 15% of the total allocation. [97] Furthermore, there are a number of national resources and investment incentives, that are annually allocated in science, research and competitiveness. The problem is, that until recently grant sources were poorly drawn, investment incentives mean market failures and resources pointed into research and development are not always used for projects with the desired final output.

The current situation reflects still low level of development of domestic knowledge base and the limited extent and weak intensity of innovation activities of enterprises. Consequence is the dependence of Czech business sector on imported and very expensive and for many business entities financially unattainable foreign licenses, technical skills and know-how, machinery and advanced technologies. This dependence is manifested by long lasting "undercapitalisation" of production and technological bases of industry, most part in small and medium-sized enterprises and slowly progressive restructuring, where survive qualitatively less intensive productions in many industries. [91] [108]

A brief description of the problem and opportunities shows, that the issue is not possible to describe by exact form of the function and thus it will be necessary to choose methods, that can be applied, even if the exact form of the function of solved problem is not known. This Dissertation primarily uses modeling and simulation to find the optimum combination of all following variables, so the effects, which the implemented science park will bring for both the science park itself, and for recovery of the regional economy are maximum. Modeling is a relatively new area of activity involving a large number of ideas from different disciplines and is an essential and integral part of all scientific activities. Modeling techniques include the use of statistical methods, computer simulations, identification systems and sensitivity analysis. All these methods are important, but most important is the ability to understand the basic dynamics of complex systems. This overview is needed to assess whether the assumptions in the model are correct and complete. Modeler must be able to recognize whether the model reflects reality, and identify and resolve the differences between theory and actual data obtained. The system must be reliable and flexible enough to meet the requirements of the real world and all relevant decision-makers, who will use it, when making decisions about investment in SP.

Optimization is a term, that is used in many different areas. Many of the activities and processes use resources, while there is a continuous need to improve the effectiveness of their spending. For businesses is inevitable to optimize the consumption of their resources.

2. Research objectives

Managements of a broad spectrum of companies, high tech companies in particular, see identification of trends as the key factor of their competitive advantage. Therefore a deep understanding of the very nature of trends is essential for strategic SPs foresight. [35] [31] [59]. Modern computers are extremely powerful tools in terms of number manipulation. However, their contribution to solving complex problems using common sense has been practically very small. [42]

INMS are such systems which are, by their very nature, difficult to measure/observe and of course to model.

This research is conducted with the intention to develop a qualitative SP models using just trend descriptions.

2.1 Primary objective of this research:

To build up SP modeling/decision making methodologies based on qualitative SP models using just descriptions based on three values, namely positive, zero, negative. Naturally if qualitative information items are used as the only information input into a model then the results are exclusively qualitative ones.

2.2 Secondary objectives of this research:

To verify algorithms which are based on qualitative modeling and built up SP methodology of vague analysis/optimization/decision making.

The basic philosophy is simple - Vague knowledge must not be modified to fit the network of available calculi but the calculi must be made so flexible that they can formalize and integrate vague and inconsistent knowledge with the minimum amount of knowledge loss.

One has to keep in mind the obvious fact that a formalized engineering problem is a solved problem. Thanks to the development of computer hardware and software, the mathematical solution itself does not usually represent a major problem.

However, real life problems often involve data which are vague, inconsistent and sparse. The crucial step towards the final solution is the reconciliation of all relevant data. Human thought is not based on equations and the most powerful tool used by human beings to solve real problems is common sense reasoning. A qualitative model is the best available calculus which can be used as a theoretical background to formalize common sense reasoning.

3. Methods used in this research

This research is closely related to optimization of poorly-known, nonlinear, multidimensional systems as SP. As it was already said it is very problematic to model and optimize SP because available information is vague, sparse and heavily inconsistent. The key problem is information shortage, which has the same reason as any study of a prohibitively complex system. [51] [23] The most difficult aspects are:

- data acquisition problems
  - insufficient numbers of observations
  - prohibitively low accuracy of some observations
  - some variables cannot be measured/quantified and their observations are based on purely subjective evaluations
- knowledge insufficiency
  - process models are oversimplified
  - deep knowledge is limited
  - important relations are not known
  - several principally different explanations of behaviors based on inconsistent pseudo deep knowledge exist

These scientific methods will be used in this research:

- Qualitative Models
- Unsteady State Qualitative Models
- Qualitative Transitions
- Qualitative Multi-Objective Optimization and/or Decision Making

The details about the specifics of each of these methods is discussed further in the dissertation and future publications. Each use of these scientific methods will be similar to a certain degree of their use in different research, but there are going to be unique and very interesting characteristics. This research is a great challenge that requires the knowledge and expertise of several researchers. The conducted research brings new views to several areas and examines the relations that have not been studied before. The results of this research will be usable in the real world. It is therefore very important to analyze the use of these scientific methods to ensure that no important steps are ignored or incorrect conclusions made.

4. An overview of the current state of the problem, which is subject of dissertation

4.1 Definitions

This Disertation deals with optimization of science parks for use of future investors as a decision support algorithm. This chapter contains general information about the science parks, research institutions, small and medium-sized enterprises, high-tech companies, technology platforms, innovation and opportunities for their funding, regional innovation policy and regional innovation system.

4.1.1 Science and Technology Park

A **science park** or **science and technology park** is an area with a collection of buildings dedicated to scientific research on a business footing. There are many approximate synonyms for "science park", including **research park**, **technology park**, **technopolis** and **biomedical park**. These parks differ from typical high-technology business districts and from science centres in being concerned with future developments in science and technology. Typically businesses and organizations in the parks focus on product advancement and innovation as opposed to industrial parks, that focus on manufacturing and business parks, that focus on administration. The park offers considerable advantages to hosted companies, by reducing overhead costs with these facilities. Science and technology parks are encouraged by local government, in order to attract new companies to towns, and to expand their tax base and employment opportunities to citizens. [104]

Technology Park's are business infrastructures contributing to the growth of the economic level of the region by promoting development and growth of companies with an interesting idea and focus. Often, science parks are associated with or operated by institutions of higher education (colleges and universities). This leads to a rapid transfer of information from research institutes to companies. Except renting of space park also offers a service of business incubator. The business incubator is a combination of subsidized (discounted) rental for young innovative companies (companies with an interesting idea and focus), together with advisory services, that these companies need (help with business strategy, with marketing and promotion, providing finance, accounting, legal services etc.). Part of science and technology park is also a center for technology transfer to help commercialize research results in business practice. [106] Science parks in Czech Republic are grouped into the Science and Technology Parks. [95]

The concept of science parks abroad, particularly in developed countries of the European Union, has been used for several decades. For the construction and operation of science and technology park is possible to obtain a subsidy programming period 2007-2013. [106] This option is likely until 2020.

4.1.2 Business incubator

It is an environment (building or a small industrial zone) for startup companies. Incubator helps to create a base for companies, whose main business is the development of new products, technologies or services and their placing on the market. These include companies with good ideas, but they have lack of funds and expertise for its implementation. Incubator helps to create conditions, which help young innovative companies to realize their ideas into final form offer them on the market in a reasonable timeframe. This started small companies usually don’t have so much trouble to find a private investor. Rental price and related services are usually subsidized by government programs to support small and medium enterprises. [105] In Czech republic Business incubators rise on the initiative of regions and cities or as associated universities and colleges workplace. However, you can also find incubators operating without public support and built on a purely profit-principal. Currently a a few dozen of these entities work in the Czech Republic. [87]

4.1.3 Innovations

Innovation means renewal and extension of the range of products and services and related markets, creating new methods of purchasing, production and distribution, introducing changes in management, work organization, working conditions and skills of the workforce. Innovation is often seen only as technical parameters of products. In fact, innovation must focus on all business activities - the purchase and consumption of raw materials, technology, organization, management, marketing methods, service and sales personnel. Everything the company pulls forward and gives effect to be included into innovative projects. [5]

4.1.4 Research institute

A research institute is an establishment endowed for doing research. Research institutes may specialize in basic research or may be oriented to applied research. Although the term often implies scientific research, there are also many research institutes in the social sciences as well, especially for sociological and historical research purposes. [107]

Research organization means an entity (such as a university or research institute), regardless of legal status (under public or private law) or way of financing, whose primary purpose is to conduct basic research, applied research or experimental development and to disseminate their results through teaching, publishing or technology transfer. All profits are reinvested in these activities, the dissemination of their results or teaching. This is a Public Research Institution (under Act No. 341/2005 Coll.), Universities (under Act No. 111/1998 Coll.), Contributory Organizations (under Act No. 219/2002 Coll. No. 250/2000 Coll.) Government Departments (under Act No. 219/2000 Coll.) Branch of Local Government (under Act No. 250/2000 Coll.) and other organizations meeting the requirements under § 28 of Act No. 130/2002 Coll. on the support of research and development. [103]

4.1.5 The definition of micro, small and medium-sized enterprises

For micro, small and medium enterprises is considered to be an entrepreneur, who employs fewer than 250 employees and an annual turnover is not exceeding 50 million EUR or total annual balance sheet does not exceed 43 million EUR.

- Within the SME category a small enterprises are defined as enterprises, which employ fewer than 50 persons and whose total annual turnover or annual balance sheet does not exceed 10 million EUR.
- Within the category of small and medium-sized enterprises are defined as small business entrepreneurs, those who employ fewer than 10 persons and whose total annual turnover or annual balance sheet does not exceed 2 million EUR. [73]

4.1.6 Spin off firma

Is a company, formed in such a way that one or more employees leave the mother organization, to create a new, secondary companies, however, significantly based on the primary elements of work of the mother company they leave. Mother company has usually dominant influence in new company. [85]

4.1.7 Hi-tech and medium-high-tech industry

The industries with high technological intensity are defined by the OECD methodology, and their inclusion is decided based on the share of R & D expenditure and added value. Among the high-tech field belong sector with NACE codes 24.4, 30, 32, 33 and 35.3, which are e.g. pharmaceuticals, computers, aircraft and medical equipment, the medium high-tech ranks sectors with NACE codes 24, 34.4, 29, 31, 34, 35, 35.1 and 35.3, which is e.g. automotive, electrical machinery, chemicals, etc. [4]

4.1.8 European Technology Platforms (ETPs)

Bring together all interested "players" such as industrial enterprises, research and financial institutions, national public authorities, users and consumers involved in research, development and innovation in strategically important technology areas at the national or international level. [26] [74] The aim of such groups is to create a medium-to long-term vision of future technological development, including significant issues regarding the future economic growth, competitiveness and sustainable development in Europe. One of the first and major steps in the development of platform is to develop a strategic document on research (technology) area defining scientific research priorities and possible timeline for their research (SRA - Strategic Research Agenda). The document also includes procedures on how to mobilize resources (including financial support for national research, Structural Funds, EU Framework Programmes, the European Investment Bank, Eureka) to realize the vision and the subsequent application of the results. [98]

ETPs provide a framework for stakeholders, led by industry, to define research priorities and action plans on a number of technological areas where achieving EU growth, competitiveness and sustainability requires major research and technological advances in the medium to long term. Some European Technology Platforms are loose networks, that come together in annual meetings, but others are establishing legal structures with membership fees.

ETPs foster effective public-private partnerships, contributing significantly to the development of a European Research Area of knowledge for growth. Public-private partnerships can address technological challenges that could be key for sustainable development, for the improved delivery of public services and for the restructuring of traditional industrial sectors. [78]

Shaping the Community research priorities — The seventh framework programme (FP7) was launched at the end of 2006: ETPs helped to shape FP7 and have continued to contribute their suggestions to the yearly work programmes. At the same time, successful project proposals submitted by ETP members have already been launched as FP-funded research projects.

Platform operations — While many ETPs financed the launch of their activities with the support of framework programme funds, these projects are now over or coming to an end. Several platforms have already acquired legal entity status, establishing themselves as non-profit organisations with membership fees. Some platforms have also moved forward in professionalising their activities, for example by creating databases of research projects carried out by their members. [79] List of individual ETPs see the attached Fig. 22.

4.1.9 National Technology Platforms (NTP)

Many European countries have very similar sets of goals in competitiveness in a knowledge economy and thus creates a lot of National Technology Platforms (NTP). List of National Technology Platformes see attached Table 8.

<u>The main objectives of NTP are:</u>

- tionships of regional "key players" (industry, SMEs, R&D institutions, universities).
- increase the participation of SMEs (SMEs as the driving force of innovation)
- define a list of research needs
- implement suitable training and educational strategy
- provide feedback to ETP
- identify and shape the national/regional research program
- identify the differences between national and EU policy and legislation
- identify possible national financial support
- implement a joint research and development [26]

4.1.10 Knowledge economy

It consists in creating added value by making use of knowledge and it grows in importance of education and utilization of scientific knowledge in terms of overall competitiveness of the country. [15]

4.1.11 Qualified workforce

A highly qualified workforce, that is able to respond flexibly to a rapidly changing environment is a assumption for the proper functioning of the economy in today's globalized world. In terms of education and skills the key areas are educational structure (the proportion of secondary school and university-educated population), the quality of the education system and training of employees. [92] Higher education and lifelong learning, promotes flexibility and employment of citizens on the labor market, thereby it significantly increases the competitiveness of the country and its regions. Primary and secondary education is very important and represents an essential building block for education of the whole population. But it is higher education and lifelong learning, through which rise a highly skilled workforce, which is flexible and ready o react to sudden changes associated with technological innovation and globalization.

4.1.12 Living utilities are:

Public establishments - it is a non-commercially used devices, that are not able to capitalize on their operation, but is still needed to work. Operation of these devices is in care of the village, because there is no interest about them from the side of entrepreneurs. This category is one of almost all educational facilities, cultural, health and social care.

Commercial device - basically a whole network of shops, accommodation and catering equipment and services. [100]

4.1.13 Competitiveness

World Economic Forum defines competitiveness as "a set of institutions, policies and factors, that determine the level of productivity of the country." It depends on the productivity and prosperity, that reaches a given state. This means, that more competitive economies reach higher levels of income of its citizens. The level of prosperity also determines the rate of return on investment and this has an impact on economic growth. Thus, more competitive countries in the medium and long term achieve higher growth. [4]

4.1.14 Grants

Within the Operational Programme Research and Development for Innovation grants may be drawn under the following priority axes:

Priority axis 1 – European Centres of Excellence

The main objective of the intervention is creation of a limited number of Centres of Excellence, well equipped R&D centres with modern, sometimes unique research infrastructure, with a critical size and able to contribute to the networking and closer integration of the leading Czech R&D teams with leading international research organisations and European research infrastructures. [96]

Priority axis 2 – Regional R&D Centres

The objective of regional R&D centres is to fulfil the function of a relevant research partner for collaboration with the application sphere (enterprises, hospitals, etc.), including partnerships with innovative small and medium-sized enterprises (SME‟ s) and clusters. Through the advancement of knowledge in the respective domain, adaptation and transfer of technology and know-how, these centres will be able to contribute in an important way to the competitiveness of the economy of Czech regions. [96]

Priority axis 3 – Commercialisation and popularisation of R&D

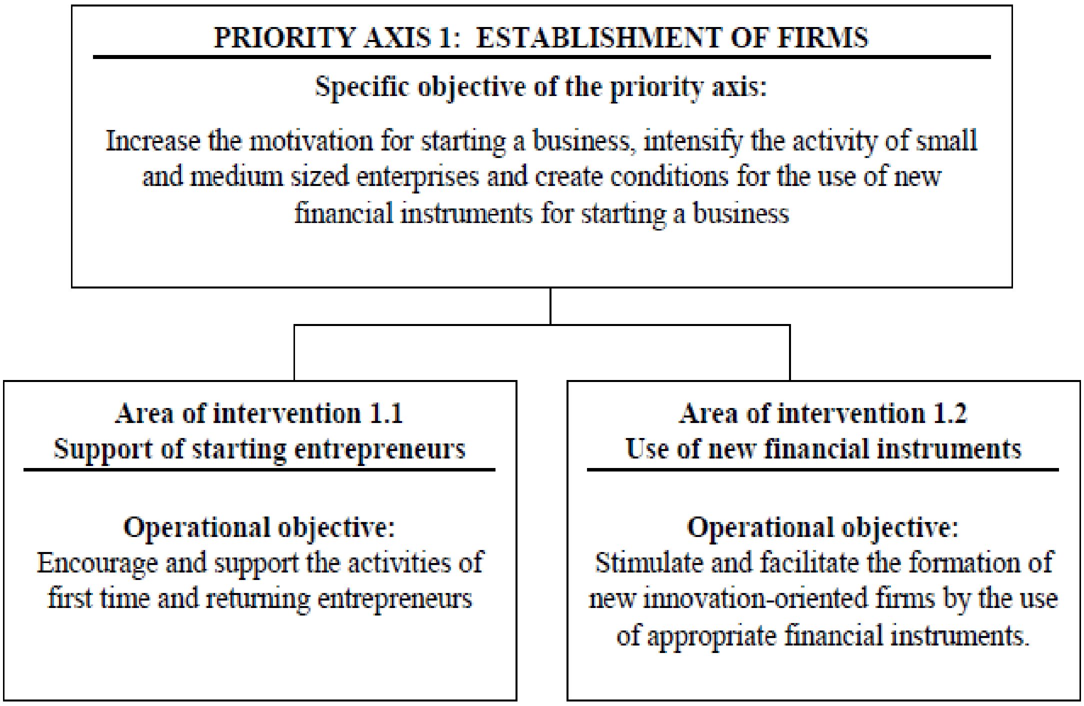
This priority axis concentrates support for several horizontal, cross-cutting themes, which are crucial for successful implementation of projects under priority axes 1 and 2. Firstly, it aims to create conditions in research organisations for the successful commercialisation of the results of R&D activity, enhance the system of the intellectual property protection and support establishment of new technology-oriented firms. Secondly, the priority also aims to improve the system of providing information on R&D results, availability of R&D information, contribute to promotion and popularisation of research, improve the evaluation system of research organisations while using foreign experience and contribute to making the public support for R&D more effective. [96]

Priority axis 4 – Infrastructure for university education related to research

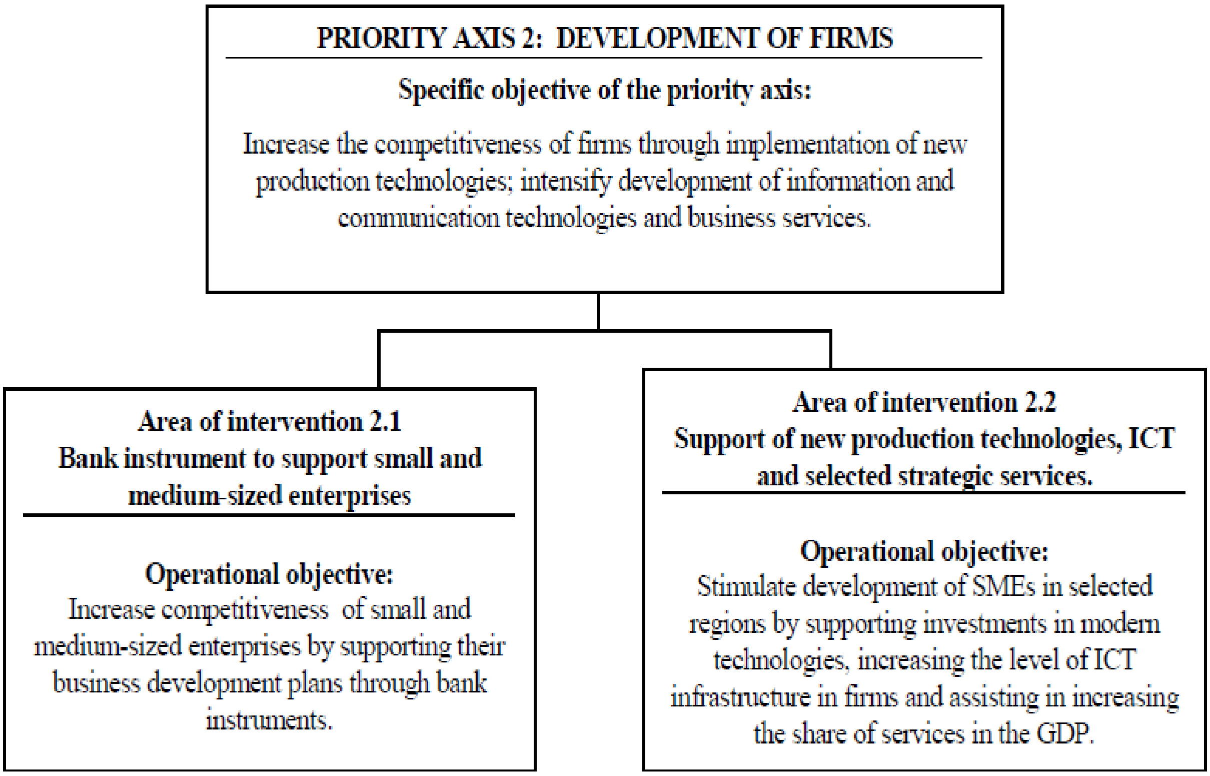
Supported area 4.1. – Infrastructure for university education related to research

The main objective of the priority is to support development of a quality infrastructure of universities with the purpose of increasing the capacity of tertiary education and creating conditions for the improvement of the quality of education. This type of investment represents a prerequisite for a necessary quantitative and qualitative increase in supply of human resources for research and innovation. [96]

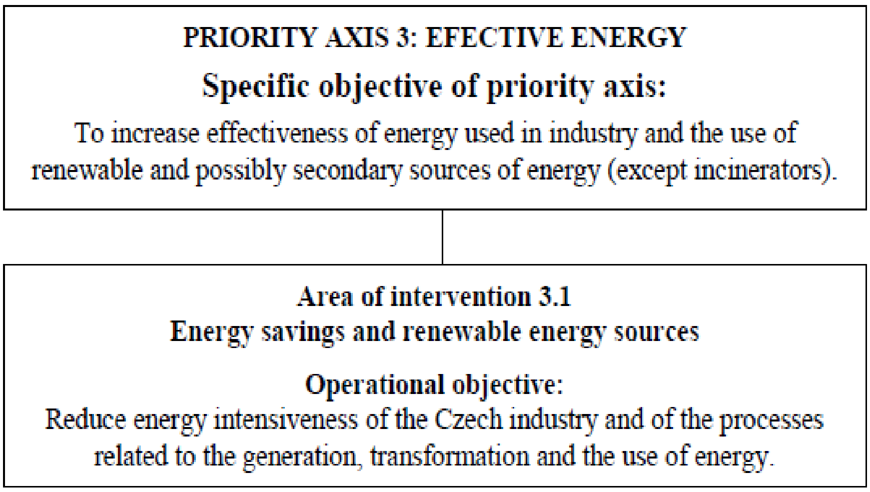
Within the Operational Programme Enterprise and Innovation grants may be drawn under the following priority axes:



Priority axis 1 - „Establishment of firms [91]



Priority axis 2 - „Development of firms“[91]



Priority axis 3 – "Effective energy" [91]

PRIORITY AXIS 4: INNOVATION

Specific objective of the Priority axis:

To strengthen innovative activities of firms

(implementation of innovative technologies, products and services)

Area of intervention 4.1
Increasing the innovative performance of firms

Operational objective:
Stimulate innovative activities of enterprises (namely small and medium-sized ones), increase intensiveness of the use of instruments for intellectual property protection.

Area of intervention 4.2
Capacities for industrial research and development

Operational objective:
Increase research and development capacities of enterprises (namely small and medium-sized ones); intensify cooperation between firms and research and development institutions.

Priority axis 4 – „Innovation"[91]

PRIORITY AXIS 5: ENVIRONMENT FOR ENTERPRISE AND INNOVATION

Specific objective of the priority axis:

To encourage cooperation of industry sector with R&D organisations, to increase quality of infrastructure for industrial research, technology development and innovation, to increase effectiveness of human resources in industry and to increase quality of infrastructure for enterprise.

Area of intervention 5.1
Cooperation platforms

Operational objective:
To create infrastructure for development of cooperation of firms with research and development and educational institutions, increase quality and extend infrastructure for innovative business.

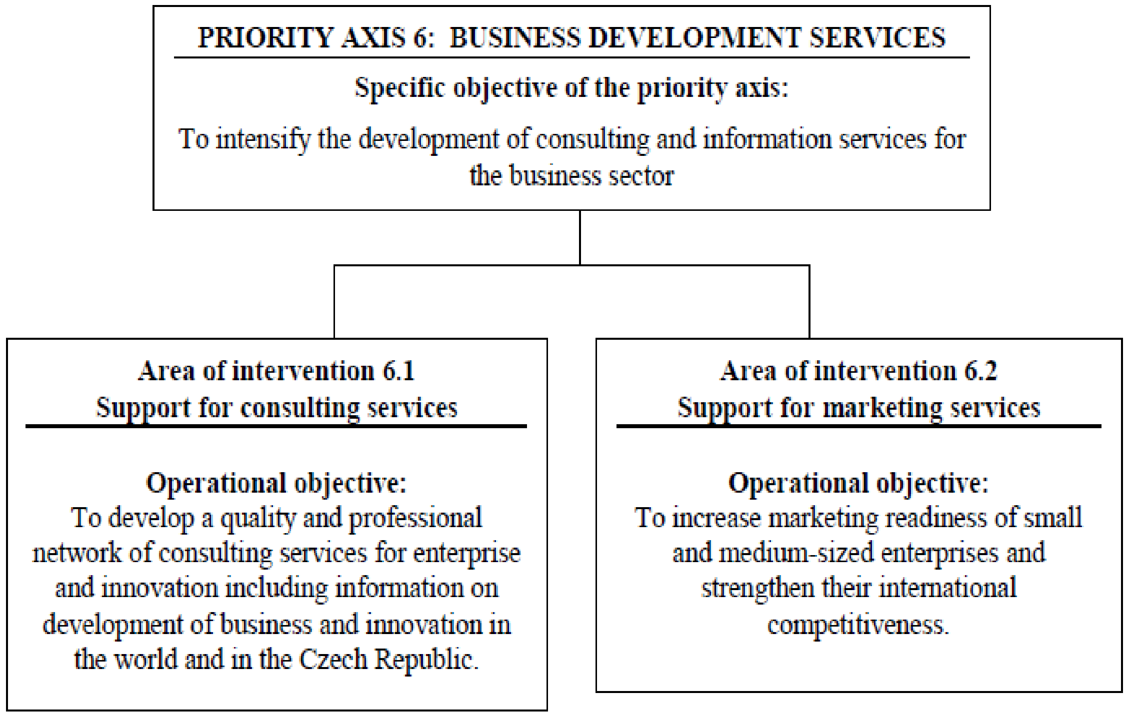
Area of intervention 5.2
Infrastructure for human resources' development

Operational objective:
To develop quality infrastructure for education and human resources development in industry.

Area of intervention 5.3
Infrastructure for enterprise

Operational objective:
To increase quality and extend infrastructure for enterprise in the area of commercial real estate development and regeneration of brownfields.

Priority axis 5 – „Environment for enterprise and innovation"[91]



Priority axis 6 – „Business development services [91]

Within the Operational Programme Education for Competitiveness can draw grants under the following priority axes:

Priority Axis 1: Initial Education

Areas of support:

- 1.1 Increasing quality in education
- 1.2 Equal opportunities for children and pupils, including the children and pupils with special educational needs
- 1.3 Further Education for the employees of schools and school facilities

Priority Axis 2: Tertiary Education, Research and Development

Areas of support:

- 2.1 Higher vocational education
- 2.2 Tertiary education
- 2.3 Human resources in research and development
- 2.4 Partnerships and networks

Priority Axis 3: Further Education

Areas of support:

- 3.1 Individual further education
- 3.2 Support for the offer of further education

Priority Axis 4 (a, b): System Framework for Lifelong Learning (Convergence Goal, Regional Competitiveness and Employment Goal)

Areas of support:

- 4.1 System framework for initial education
- 4.2 System framework for tertiary education and the development of human resources in research and development
- 4.3 System framework for further education

Priority Axis 5 (a, b): Technical Assistance (Convergence Goal, Regional Competitiveness and Employment Goal) Oblasti podpory:

Areas of support:

- 5.1 Management, control, monitoring and assessment of the programme
- 5.2 Awareness and publicity of the programme
- 5.3 Absorption capacity of the entities implementing the programme [94]

Within the Operational Programme Prague Competitiveness is possible to draw funding under priority axis 3 Innovation and entrepreneurship:

In the area of support 3.1 - **Developing an innovative environment and partnership between the research and development and practice** can be supported e.g. the development of innovation infrastructure (science parks, incubators, innovation centers, centers of excellence), the creation of partnerships between research institutes, the Academy of Sciences, universities and businesses, establishment of counseling and information centers for innovation and technology transfer, etc.

In the area of support 3.2 - **Promoting a favorable business environment** fund can be drawn e.g. to support activities such as the development of innovation capabilities of existing businesses, stimulating new forms of cooperation between companies, local government, business associations (especially Chambers of commerce), non-profit sector, and other research institutions (e.g. clusters, etc.), construction consultancy, eventually specialized training centers for employees and managers of SMEs, sheltered workshops, logistics centers to care for handicapped, base of public works, implementation of infrastructure for tourism, etc.

In the area of support 3.3 - **Development of small and medium-sized** enterprises will be supported the development of SMEs in the form of direct subsidies. [83]

4.1.15 Nature of regional innovation policy

The essence is to search for such a model of promoting innovative activities of companies in the regions, that allows local actors from the academic, public and especially private sector to cooperate in the use of specific conditions and potential of the region for creation of unique and globally applicable competitive advantage.

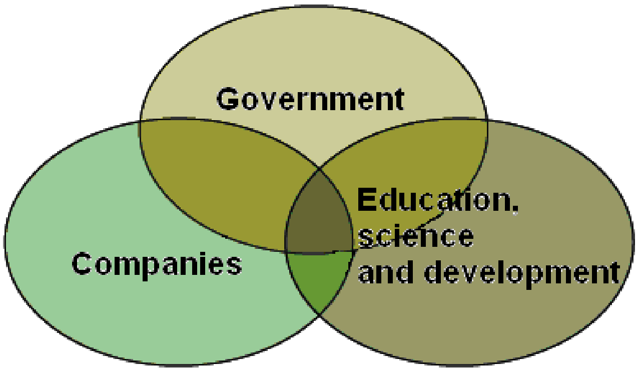


Fig. 1 - Triple Helix [89]

These three spheres: academic-research, companies and government form peaks known as the Triple Helix underlying any innovation system - even at the regional level. [89]

4.1.16 Regional innovation system

Regional Innovation System (RIS) is a network of companies and institutions including an intensive exchange of information among them and leads to various forms of cooperation, that supports innovative activities of companies and hence their productivity. RIS are characterized mainly by the advanced coordination mechanisms, use of advanced technologies, the presence of educated and highly demanding local demand.

A key competitive advantage is the innovation process itself – i.e. the ability of local actors to innovate = combine the local conditions with unique knowledge and skills and support infrastructure to meet global demand. This process and related skills are different from region to region and hardly portable! Decisive is not subject of innovations, the existence or absence of a specific organization – crucial is the ability to innovate (and to learn to innovate) at a critical amount of subjects in a given locality/region using site-specific conditions. [89]

4.2 The current state of the problem

Structural aspects of development

Disparities are even wider across EU regions. According to the latest data available, expenditure on R&D in the EU averaged around 1.9% of GDP in 2007. Expenditure, however, ranged from 5–6% of GDP in Braunschweig and Stuttgart in Germany and Västsverige in Sweden to less than 0.1% in Severen tsentralen in Bulgaria and Lubuskie in Poland. Expenditure exceeds the Europe 2020 target of 3% in only one in 10 regions, while it is less than 1% in almost half (48%) the regions (Fig. 27). In 2007, almost none of the lagging regions had R&D expenditure levels above 2% (the Barcelona target for business R&D). The only exception is Stredni Cechy (the region surrounding Prague) where business R&D expenditure amounts to about 2.5% of GDP see attached Fig. 27. [81]

The position of CR in international comparison

Czech Republic is at the 36th place in the latest comparison of international competitiveness. Especially in last 5 years CR felt in a world and european kontext a noticeable decline in competitiveness, which is necessary to stop and reverse the negative trend. This change can occur only through systemic changes.

Additionally to changes can operate effectively set up and managed development strategies and policies and the resulting specific interventions from public sources. Development activities should help to use best the economic potential, to focus on eliminating or at least mitigate the identified deficiencies and flexibly and appropriately respond to current trends in Europe and the world. [64]

Reinforcing priorities of Europe 2020:

- Smart growth: developing an economy based on knowledge and innovation.
- Sustainable growth: promoting greener and more competitive economy less demanding on resources.
- Inclusive growth: promoting a high-employment economy, which will deliver social and territorial cohesion

EU's main objectives:

- 75% of the population aged from 20 to 64 years should be employed,
- 3% of EU GDP should be invested in research and development,
- Climate and energy should achieve objectives "20-20-20" (including an increase commitment to reduce emissions to 30% if the conditions are favorable)
- The proportion of early school leavers should be below 10% and at least 40% of the younger generation should rich tertiary education,
- Number of persons at risk of poverty would drop by 20 million [82]

Long-term sustainable strategy to increase competitiveness of CR in the European and global context must be based on strengthening the competitiveness of those factors, which depend not only on low-cost companies and relatively cheap labor, making CR still gaining ground in international comparison.

An integral part of the strategy must also be reducing external costs and barriers to business. Area of Competitiveness of Czech Republic will built on four pillars:

- business development, entrepreneurship and use of innovation
- functioning labor market
- development of education
- support for promotion of innovation and research and development

Business in CR must be more than ever based on the use of innovation, leading to the growth of its productivity. Companies must be progressively more involved in to global division of labor on a higher qualitatively level position in value chains.

So far the instruments used for business support must be properly configured to secure modern infrastructure for business, expanded range of services for entrepreneurs and more motivation for entrepreneurship. This will allow businesses more efficient use of available resources for business development. Financial engineering tools will be used to a greater extent than at present to promote entrepreneurship. [93]

Weaknesses of Czech competitiveness

As the greatest long-term obstacles in the development of Czech economy are identified very poorly functioning Public administration institutions (at national and local level), an unfinished infrastructure network inadequate to current needs of the economy and society. These are significant barriers for the Czech economy with a small domestic market and a high degree of openness - and a significant export orientation.

Serious deficit and negative trends were also identified in the public education at all levels. Not too good current status can due to current trends in these areas lead to further degradation of the situation. Specifically in the area of education is evident neither fall into spheres not matching the advancement or future needs of Czech Republic and not corresponding with the current or future demand of business or public sector for a competitive workforce.

Another problem affecting the long-term competitiveness of Czech Republic is the widening of regional disparities in performance below the level of NUTS III - regions. Significant growth potential of the country is limited to certain urbanized parts of the country, which have an objective assumptions for competitive growth with emphasis on strengthening the innovative activities of companies. [64]

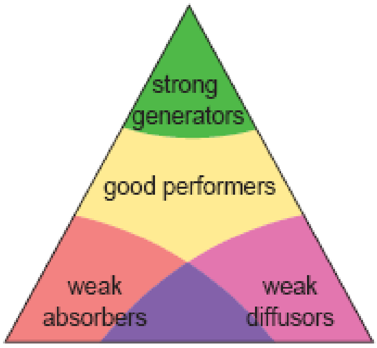


Fig.2 - Regional innovation potential in EU regions [81]

The first group (labelled as strong generators of innovation) includes regions which are close to the global technology frontier, which are mostly located in the highly developed North-Western Member States. Their main characteristic is the capacity to produce new technologies, and their growth process hinges on R&D and innovation as well as on the accumulation of human capital in order to move the technology frontier outwards.

The second group (labelled as weak absorbers) are regions which are catching up on the first group through a process of technology absorption, which requires high levels of human capital. The main challenge for these regions is therefore to increase the education level of the workforce. They broadly correspond to the moderately developed regions in the EU.

The third group (labelled as weak diffusers) comprises regions mostly located in the EU-12 countries, which are catching up on the first group at an even faster pace. This process is generally based on the restructuring of their economies and critically rests on their capacity to bendit from technology diffusion. For these regions where the level of education is often relatively high, the main limiting factor is their low endowment of infrastructure and the nature of the business environment see attached Fig. 29. [81]

Characteristics of the innovation potential of CR regions

Technology Centre of Academy of Science of Czech Republic conducted an investigation of the innovation potential of regions in CR.

Among the results were those findings:

<u>Institutions of innovative infrastructure</u> (science and technology parks, technology and innovation centers, technology transfer, business incubators, advisory bodies and other bodies of innovative business).

<u>Institution of regional development</u> (regional development agencies, county chambers of commerce, regional authorities, regional advisory and information centers).

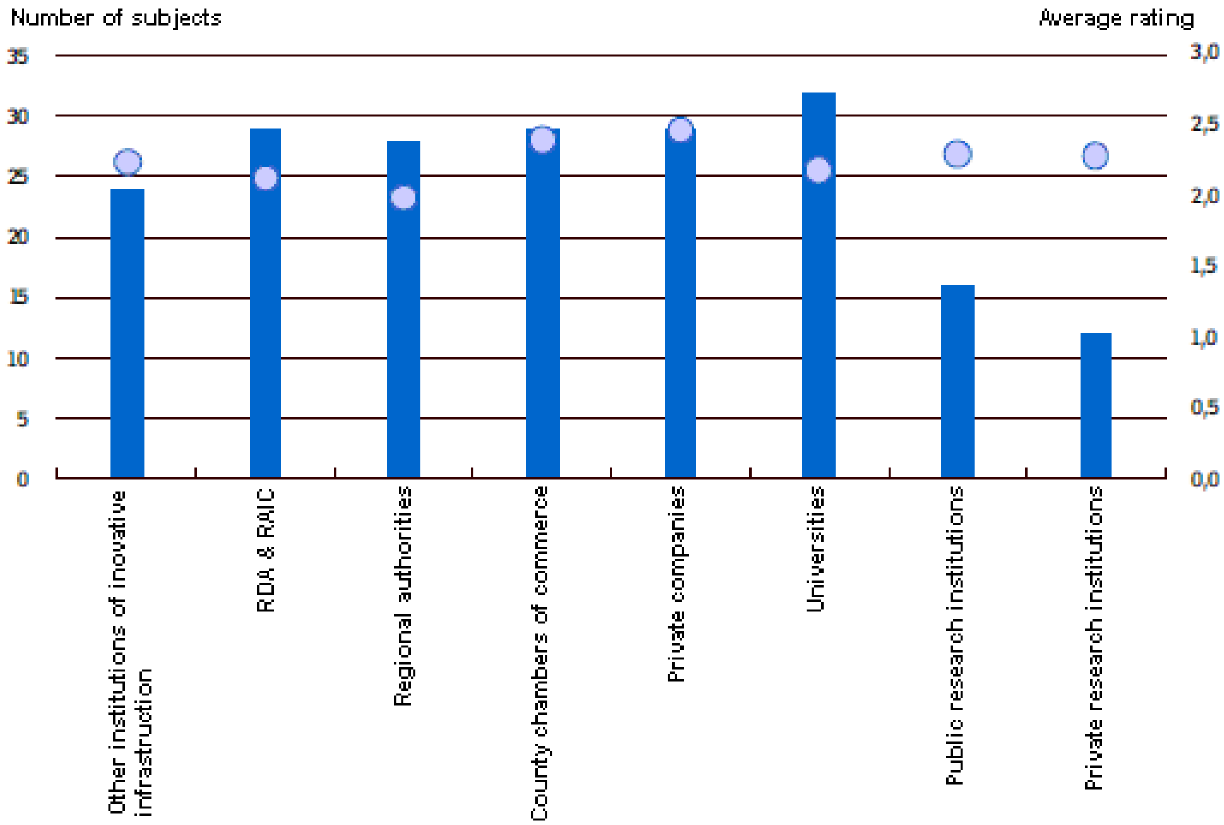


Fig. 3 - Evaluation of cooperation of institutions of innovative infrastructure and institutions of regional development with other public and private entities in each region [1]

- Number of subjects evaluating cooperation
- Average rating of cooperation

Explanation: Cooperation with other entities in each region was evaluated by respondents on a scale of 1 to 5, where 1 = excellent and 5 = very problematic. The average evaluation of the cooperation are reflected in the graph. *Institutions of innovative infrastructure* = science and technology parks, business incubators, technology and innovation centers, etc. *RDA* = Regional Development Agencies. *RAIC* = Regional Advisory and Information Center.

To find links between institutions of innovation infrastructure/institutions of regional development with other entities in the regions, the institutions were asked to rate collaboration with these other entities (see Fig. 3) on a scale from 1 ("excellent") to 5 ("very problematic”). The analysis showed, that institutions often collaborate with universities, which are also rated as very good partner for cooperation. Better ratings received only regional authorities and regional development agencies, along with regional advisory and information centers. Less frequently cooperate responded entities with (other) institutions of innovative infrastructure, what can be explained in case of cooperation between institutions of innovative infrastructure in one region by the strong competition among these entities, often oriented to obtain the same contract. Least contacts is working between interviewed subjects and research organizations - from public, but also private sector. Private research institutions were also frequently rated as the most problematic partner for cooperation from the offered options. In connection with the above fact is not surprising, that almost half of the surveyed institutions does not cooperate with anyresearch center. Institutions, that collaborate with research institutes, reported as the most common partners university workplaces (18 from 40 interviewed subjects), less frequently then departmental research facilities or Academy of Sciences (9 subjects) or other research institutes and companies (10 subjects). [1]

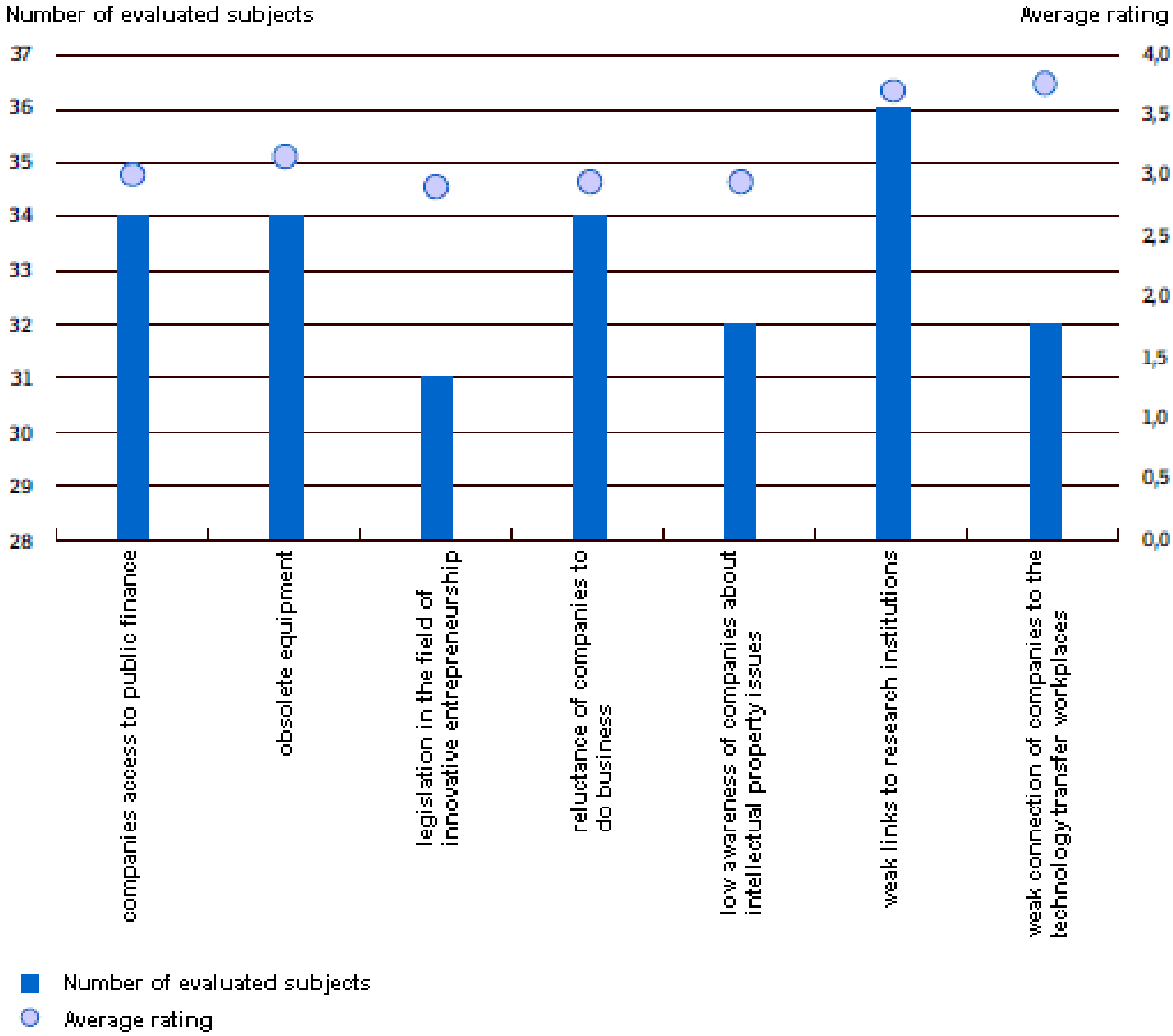


Fig. 4 - Barriers to the creation of innovation by companies [1]

Explanation: Barriers to the creation of innovations by companies were evaluated based on the experience of surveyed institutions, and only for the county in which the institution is located. Evaluation was based on the importance, that respondents attributed the problems listed in the questionnaire, where 1 = minimal (problem) and 5 = maximum (problem). Average rating of barriers according to the significance are listed in the graph.

As the main problem for innovative business was marked weak links between companies and scientific research institutions and workplaces of technology transfer and knowledge transfer. This result corresponds with the low intensity of cooperation between research institutions and innovative infrastructure and regional development institutions. It is not just a question of connection between businesses - research.

Among other possible barriers to business innovation was named for example the problem of lack of human resources capable of solving innovation in companies and the Higher Education Act and its lack of effect on the motivation of researchers, etc. [1]

Innovative performance of companies is generally considered an important component of long-term competitiveness of countries and regions. This opinion respects the global changes in economic environment, which in developed countries have raised demand for new development strategies associated with the transition to the knowledge economy based on innovation, science and research and education of the population.

In this context, the EU developed the so-called Lisbon strategy, to whose practical implementation will be in the planning period 2007-2013, spent the critical part of the funds allocated within the Policy of economic and social cohesion (about 200 billion of the total 350 billion Euros). Its implementation, however, has not yielded very convincing results, which led to its revision. In one of the major causes is also considered to be little emphasis placed on her account in regional politics. [2]

Overall assessment of regional competitiveness

Table 1 - Overall evaluation of regional competitiveness [3]

Type group and subgroup	Region	Classification group		
		QBE	UHR	IPC
Type A:				
1	Prague	1	1	1
3	Central Bohemia	2	1	1
Type B:				
1	Pardubice	2	2	2
1	Liberec	2	2	2
2	Pilsen	2	1	2
2	South-Moravian	2	2	1
2	Hradec Králové	2	1	3
2	South-Bohemian	2	1	3
Type C:				
1	Karlovy Vary	3	3	3
1	Ustí	3	3	3
1	Moravian-Silesian	3	3	3
2	Vysočina	3	2	3
2	Olomouc	3	3	2
3	Zlín	3	2	2

1, 2, 3: type supgroup of regions

Type A - regions with an excellent competitive position

In to the first type A was included only Prague and Central Bohemia connected with Prague by intense relationships. These regions have the best conditions for dynamic economic development, ensuring their continuing prosperity and in accordance with the optimal strategy can be considered progressive scenario of their economic development.

Overall, the primary area for public intervention (especially in the case of Prague) is considered the quality of life. The analyzes show clearly irreplaceable role of Prague as the most important economic and administrative center of Czech Republic, which is the only fully functional development pole of transnational, or European importance, with strong integration potenttial corresponding with its dominant role in domestic demand.

The dominant economic position of Prague, of course positively affects the surrounding Central Bohemia Region, which is currently the Region NUTS 2 Central Bohemia. Both NUTS 2 regions undoubtedly have a high attraction for locating domestic and foreign investment and the development of economic activities with high added value. [3]

Type B - regions with a good competitive position

To this type B belong the regions of Pilsen, South Bohemia, Hradec Králové, Pardubice, Liberec and South Moravia. Overall, the regions included in this type B have the necessary preconditions for achieving an average economic level of regions of the old EU member states in the time horizon of 15-20 years.

Pilsen and South Bohemia Region, create the Region NUTS 2 Southwest. This region covers according to the values of the indicators GDP/capita. and level of components QBE and UHR third rank, by the level of components IPC the sixth rank. In the overall evaluation Southwest region is in third place (both regions fall into the second subtype, due to favorable QBE, when Pilsen is the third most important pole of development.

Pilsen and Prague is connected by the developed west bohemia development axis of national importance which is connected to partially developed north-west bohemia axis, linking Pilsen to Karlovy Vary.

Regional integration of the region is strengthened by gradually creating multinational development axis tracking the direction of Frankfurt by built highway D 5.

Southwest Region is undoubtedly an attractive location for investment and development of economic activities with higher added value.

From an administrative point of view, the most structured region at the level NUTS 2 is Northeast Region, who as the only on consists of three regions: Hradec Králové, Pardubice and Liberec. According to achieved values of indicators GDP/capita. and level of components QBE and IPC this region belongs to the fifth rank and accordnig to the component UHR the fourth rank. Region Northeast generally occupies the fifth rank.

Hradec Králové is connected with Pardubice and Prague by eastern bohemia development axis of national importance. This priority axis in Hradec Králové region complement two axes of regional importance, including developed jicin axis connected to Mladá Boleslav.

All three included regions (especially Region of Hradec Králové) have quite good assumptions to attract investment and development of economic activities with higher added value.

South Moravian Region, together with Vysočina Region create Region NUTS 2 Southeast, which is the only one including regions classified according to the regional competitiveness in different types - Type B in case of South Moravian Region and Type C in the case of the Vysočina Region. The entire region holds according to indicators GDP/capita. and level of components QBE fourth rank, according to level of components UHR and IPC third rank, respectively fifth rank and generally occupies the fourth rank. Brno as side pole of development of international importance with medium integration potential has excellent levels of QBE.

Brno is connected with the capital city of Prague by bohemiamoravian development axis of national importance, which continues from Brno by partially developed east-moravian axis of national importance. Overall, the south-moravian capital of Brno during the economic transformation gradually took decisive role in the process of economic integration of the moravian area. From an international perspective can be considered a priority ties with Austria, which accent the viennese direction of economic cooperation. In terms of location of investments and the development of economic activities with higher added-value to high added-value is clearly attractive only the Brno agglomeration. [3]

Type C - regions with poor competitive position

In type C were included remaining Regions Ústí nad Labem, Karlovy Vary, Vysočina, Olomouc, Zlín and Moravian-Silesian Region. A suitable default strategy for these regions has adaptive scenario of economic development emphasizing the necessary restructuring of their economic base.

Regions Ústí nad Labem and Karlovy Vary belong to the Region NUTS 2 Northwest. According to values of indicators GDP/capita and level of components QBE Region Northwest occupies seventh, respectively sixth rank, in case of components UHR and IPC eighth rank and in the general assessment he is in the last, ie. the eighth rank.

In this context it should be noted, that in both regions have above-average proportion of economically sensitive industries with strong developmental links to level of unemployment, especially mining completed in the Ústí region with the chemical industry. Ústí nad Labem is connected with Prague by partially developed north-bohemian development axis of national importance, which is complemented by a short development axis of regional importance. Regional integration of Ústí region is positively influenced by border economic ties with more advanced german regions, particularly in dresden direction. Karlovy Vary are connected to Pilsen by partially developed axis of national importace. Integration links to Region Ústí nad Labem are already relatively weak. Both regions have appropriate conditions for the localization of investments and development of economic activities with a median value-added and in case of regional or selected cities with more favorable economic profile also activities with higher added value.

Region NUTS 2 Central Moravia is composed of Regions Olomouc and Zlín. According to values of indicators GDP/capita this region is at the eighth rank, in case of component QBE and UHR at the sixth rank, respectively seventh place, in case of components IPC even fourth place. In the overall evaluation is based at the sixth rank.

Region Zlín is connected to Brno by already mentioned east-moravian development axis of national importance. In contrast, the Region Olomouc, which is characteristic for a significantly higher proportion of economically sensitive sectors in comparison with the Region Zlín remains, along with Moravian-Silesian Region the only region, that is not integrated with the neighboring regions through the development axis of national importance. Both regions have suitable conditions for localization of investments and economic development activities with median added value. Agglomerations of both county seats have a very good conditions for development of activities with higher added value.

Region NUTS 2 Moravia-Silesia belong according to values of indicators GDP/capita sixth rank, according to the level of components QBE eighth rank and according to level of components UHR and IPC seventh rank. In the overall comparison Moravia-Silesia occupies the seventh rank.

An important factor associated with the problematic economic development of the whole region is fund-consuming economic structure, characterized by great sensitivity to fluctuations in global demand - Moravian-Silesian region has the highest proportion of economically sensitive sectors (metallurgical industry, mining and quarrying).

The negative effects generated by the current economic developments affecting especially the heavily urbanized regions of the satellite towns of Ostrava, built originally as a mining settlement with minimal economic base. Moravian-Silesian Region is also not integrated with the neighboring region through the development axis of national importance.

The processes of regional integration thus represents only one partially developed development axis of regional importance. Moravian-Silesian Region has suitable conditions for localization of investments and development of economic activities with median value added. In case of Ostrava and several other mostly larger cities also for localization of activities with higher added value.

From the Region NUTS 2 Southeast belongs to this type C Region Vysočina, which is within the set of all regions ranked at the tenth rank. From an international perspective will be crucial ties with Austria, emphasizing the vienna direction of economic cooperation.

Regin Vysočina has suitable conditions for localization of investments and development of economic activities with a median value added, in case of if the county town localization of investments with higher added value. [3]

Identification of innovation centers in Czech Republic:

1. innovation centers of first rank with 5 large innovative companies and with total of more than 5 thousand. employees
1. innovation centers of 2^{nd} rank with 3 large innovative companies and with total of more than 2.25 thousand employees or one company with about 3 thousand employees
2. innovation centers of third rank with 2 large innovative companies and with a total of more than 0.75 thousand employees or one company with about a thousand. employees
3. innovation centers of 4th rank with a large company with about a thousand employees
4. other residential centers. [2]

Table 2 - Placement of innovative centers (IC) 1-4 rank by region [2]

Region	**IC 1**	**IC 2**	**IC 3**	**IC 4**
Prague	1	-	-	-
Central Bohemia	1	2	18	10
South-Bohemia	-	3	4	6
Pilsen	1	-	5	5
Karlovy Vary	-	1	2	2
Ústí	-	6	3	6
Liberec	1	1	2	6
Hradec Králové	-	1	9	7
Pardubice	1	1	7	6
Vysočina	1	2	3	8
South-Moravia	1	-	5	9
Olomouc	1	2	4	5
Zlín	1	-	6	2
Moravian-Silesian	1	3	8	7
Czech Republic	10	22	76	79

The above mentioned shows, that in Prague is only one innovation center of first rank. Conversely in other regions except South Bohemia, Karlovy Vary, Ústí nad Labem and Hradec Králové region occur innovation centers of first rank as well as innovation centres of lower rank 2, 3 and 4. The largest number of innovation centers are located in the Central Bohemia Region.

Personnel working in research and development

In Czech Republic at the end of 2009, worked in research and development 50.961 employees. Therefrom 25.884 employees worked in the business sector, 11.180 employees in the government sector and 13.648 in higher education sector. Most employees in the science and development is employed in the City of Prague, followed by South Moravia, Central Bohemia, Moravia-Silesia Region, Pardubice Region, South Region, Olomouc Region, Pilsen Region, Zlín Region, Hradec Kráové Region, Liberec Region. Fewest employees in science and development work at Vysočina Region, Ústí nad Labem Region and the worst situation is in the Region Karlovy Vary.

Table 3 - R&D Personnel by region 2009 [67]

CR, regions	Total	By main sector of their employment					
		Business enterprise sector		Business enterprise sector		Business enterprise sector	
		total	women	total	women	total	women
Czech Republic	**50 961**	**25 884**	**5 266**	**11 180**	**5 197**	**13 648**	**5 253**
Prague	19 747	6 050	1 381	7 666	3 593	5 874	2 235
Middle Bohemia	5 230	4 107	824	1 112	489	9	5
South-Bohemia	2 050	899	155	596	295	510	218
Pilsen	1 951	1 047	160	95	51	810	215
Karlovy Vary	107	102	23	2	0	2	0
Ústí	736	498	174	54	28	183	84
Liberec	1 270	953	178	29	11	280	76
Hradec Králové	1 750	1 397	277	111	73	242	113
Pardubice	2 092	1 783	413	60	16	249	81
Vysočina	648	630	95	17	5	1	0
South-Moravia	8 387	3 848	692	1 297	578	3 222	1 268
Olomouc	1 996	1 144	299	16	8	820	384
Zlín	1 807	1 607	278	7	5	193	78
Moravian-Silesian	3 191	1 819	316	118	44	1 254	496

Table 4 - Science and Engineering Professionals and their average monthly gross wage: by region, 2009 [68]

CR, regions	Average monthly gross wage (CZK)								
	S&E Professionals, total			In physical, mathematical and engineering sciences			In biological and medical sciences		
	total	men	women	total	men	women	Total	men	women
Czech Republic	**42 634**	**44 569**	**36 702**	**42 479**	**43 899**	**34 708**	**43 095**	**48 048**	**38 469**
Prague	52 061	55 187	42 607	54 089	56 107	44 625	43 566	48 077	39 922
Middle Bohemia	42 998	45 231	36 690	43 340	44 654	36 733	42 172	47 531	36 655
South-Bohemia	41 626	43 796	36 444	40 086	41 801	30 574	43 370	47 321	38 669
Pilsen	40 018	40 930	36 695	38 702	39 592	32 789	44 569	49 102	40 176
Karlovy Vary	43 331	44 845	39 725	38 337	39 633	30 882	49 562	55 493	43 132
Ústí	44 988	47 498	38 523	43 747	46 086	32 517	47 205	51 447	42 447
Liberec	42 058	43 965	36 211	38 925	40 042	32 213	48 214	55 952	38 708
Hradec Králové	38 801	40 135	34 509	37 071	38 326	29 207	42 121	45 369	37 780
Pardubice	36 390	38 359	30 884	34 572	36 408	25 697	40 494	45 258	35 145
Vysočina	39 928	41 118	34 336	38 767	39 946	27 288	43 533	46 913	39 067
South-Moravia	41 374	43 382	34 178	42 156	43 659	33 560	37 964	41 235	34 949
Olomouc	40 383	41 863	36 793	35 456	36 488	29 711	47 403	54 617	39 922
Zlín	38 784	39 975	35 354	36 152	36 937	29 754	43 386	49 771	37 423
Moravian-Silesian	39 133	39 788	36 504	36 738	37 522	31 344	47 936	53 408	41 668

The highest average monthly wage receive scientists and engineers in the physical, mathematical and engineering sciences in Prague 54.089 CZK, of which men in Prague earn 56.107 CZK, while women earn 44.625 CZK. In other sciences such as in biological and medical fields, men earn 48.077 CZK and women 39.922 CZK. Least scientists in physical, mathematical and engineering sciences earn in the Pardubice Region, men earn 36.408 CZK and women 25.697 CZK. In biological and medical fields, scientists and engineers earn least in the South-Moravian Region, men earn 41.235 CZK and women 34.949 CZK.

Table 5 - Human resources in science and technology (HRST), thousand persons [69]

Indicator	2005	2006	2007	2008	2009
HRST total	**1 920.0**	**1 967.5**	**2 049.8**	**2 147.3**	**2 243.0**
of which					
Persons with tertiary education	907.1	954.6	974.8	1 050.0	1 147.2
Persons employed in science and technology occupations	1 555.1	1 576.0	1 642.5	1 691.5	1 758.7
Persons with tertiary education employed in S&T occupations (HRST core)	542.2	563.0	567.4	594.2	662.9

In 2009 the total supply of human resources in science and technology was 2.243 thousand persons, including persons with tertiary education 1.147 thousand persons. Number of employees in science and technology fields with tertiary education was 662.9 thousand, who form the core of human resources in science and technology.

Nevertheless, tertiary education is neither the only nor an automatic source of highly skilled workers. Skills upgrading at all levels can significantly increase the number of highly skilled workers, especially when linked to labour market needs — a link that can be more easily established at regional level, see attached Fig. 26. The precise number and nature of the jobs in the future — and of the skills they will require — will depend on long-term structural factors such as research, innovation, technological change, globalisation and demographic trends but also on the extent and pace of the recovery from the current economic downturn. [81]

Table 6 - Persons with tertiary education (thousand persons) [70]

cator	2005	2006	2007	2008	2009
Total	**907,1**	**954,6**	**974,8**	**1 050,0**	**1 147,2**
Males	510,8	531,6	539,2	565,1	610,2
Females	396,2	423,0	435,6	484,9	537,0
Level of tertiary education					
Higher professional	45,0	57,8	68,1	72,0	70,8
Bachelor degree	46,8	49,0	58,9	85,2	103,1
Master degree	773,9	805,4	807,6	860,8	933,3
Doctoral degree	41,3	42,4	40,2	32,0	40,0
Field of study:					
Education	164,6	170,2	175,2	179,9	190,5
Humanities and arts	63,9	67,9	69,4	74,8	83,1
Social sciences, business and law	189,0	213,5	228,0	262,7	282,0
Science	71,7	73,8	79,8	88,5	99,4
Engineering, manufacturing and construction	234,3	238,9	234,7	252,3	270,0
Agriculture	58,0	59,9	53,4	55,1	64,5
Health	87,3	91,5	96,0	93,7	107,9
Services	37,5	38,0	37,3	43,0	49,7
Other	0,5	0,9	1,0	-	0,1
Employment status:					
Labour force (total)	711,2	736,8	750,1	802,6	866,1
Employed	694,6	719,1	737,7	789,4	845,2
Unemployed	16,6	17,7	12,4	13,2	20,9
Inactive	195,8	217,7	224,6	247,4	281,2

From above mentioned follows, that the total number of tertiary graduates in 2009 compared to 2008 increased by 97.2 thousand persons. Total in 2009 completed tertiary education 1 147.2 thousand persons, of which most people obtain a master's degree 933.3 thousand persons. Doctor degree reached 40 thousand persons, which is about 8,000 more, than in the previous year 2008. The highest interest was in the social sciences and business law and engineering sciences, the lowest interest was in the services, agricultural sciences and the humanities and the arts. Of the total number of tertiary educated a 147.2 thousand persons is 20.9 thousand persons unemployed and 281.2 thousand of persons economically inactive.

Training and higher education can increase labour productivity. Higher education also tends to increase people's income and life satisfaction independently of income levels. The share of people aged 25–64 with tertiary education, however, varies greatly across regions. [81] See attached Fig. 25.

Top science centers in the Czech Republic

In Brno, grow giant Science Center CEITEC for 5.2 billion Czech koruna. Subsidy was already approved by the European Commission. In CEITEC will work six hundred of scientists, who will invent for example research military robots and nanorobots, special hydrogels, that can connect bone fracture using a syringe, dental prosthesis made of ceramic and metal materials or self-cleaning coatings buildings. [84]

Fig. 5 – Ceitec [65]

Only three weeks after the approval and the Central Institute of Technology in Brno already welcomed its international leadership. The highest science advisory body of CEITEC, whose members are exclusively important representatives of leading foreign scientific institutes met at the first meeting in Brno International Scientific Council in June 2011. These independent experts assess and approve major decisions on key issues and principles of its management. CEITEC already fully started its ambition to become the European center of excellence.

Members of the International Scientific Council:

Prof. Wolfgang Knoll, scientific director, AIT- Austrian Institute of Technology, Vienna, Austria

Prof. Hartmut Oschkinat, scientific director, Leibnitz Institut für Molekulare Pharmakologie Berlin, Germany

Prof. Dirk Inzé, scientific director and director of Plant systems biology, VIB University of Gent, Belgium

Prof. Andrés Aguilera, deputy scientific director and head of Molecular Biology, Andaluzian Center for Molecular Biology and Regenerative Medicine

Prof. Yoshio Nishi director of Science Center for Integrated Systems, Standford University, USA [66]

Besides CEITEC, the European Commission approved grant of seven billion Czech koruna to build the world's most powerful laser (ELI) in Dolní Břežany near Prague.

As a suitable location for the construction of the laser center ELI was selected village of Doloní Břežany in Region Central Bohemia. Because the ELI is an international infrastructure, which will employ more than 300 domestic and foreign workers and annually becomes the target of several hundreds of users, it´s accessibility and infrastructure of the village are extremely important.

Another benefit of this location is its easy accessibility of Prague, which allows quick contact with scientific and industrial background, concentrating mainly in Prague. [76]

A new generation of scientists

ELI device will also create an attractive platform for education of new generation of doctoral students, scientists and engineers. This will significantly increases the prestige of Czech Republic as the host country for top class international research project with open access to scientific community all around the world. ELI will also attract further investment to CR in advanced technologies with high added value. [77]

The approval by the European Commission are still waiting other four projects in large scientific centers. This applies, for example, Ostrava IT4I centre, which plans to build the largest supercomputer in the center of Central Europe, or center SUNSEN in Řež near Prague, which will develop more advanced nuclear reactors. However, there are critics, who argue, that science centers will not attract enough of scientific research capacity and bold plans will fail. [84]

Critics have analyzed that subsidies should not be wasted, e.g. to invest in new sites in rural territory and expecting scientist will move there automatically. More logical would be to point brussel´s billions into existing good research facilities rather than building up others. "Lots of money is used for the construction of new buildings and equipment. If funding would be invested into what already exists, it would be more efficient and economical. For the six centres of excelence, which should grow in Czech Republic, will European Union endow only five years. After these 5 years, these centers will have to become financially independent, either by commercial research or by enabling support from state funds. Most centers believe that they will participate in commercial research, cooperation with private entities. However it's without doubt that this will rather be an extra income, but it will not cover overall operations.[99]

In the future research projects, development and strategic business services could also draw incentives for investment. It provides for an amendment to the Act on Investment Incentives, prepared by the Ministry of Industry and Trade.

Incentives for investment in the form of tax relief can get only projects focused on production. Technology centers previously received grants from the state from special program, which according to the minister Kocourek was not an ideal solution.

Technology centers and Centers of Strategic Services was formerly in Czech Republic financially supported by a special program. According to experts from Ministery of Industry and trade and CzechInvest tax credit is administratively less demanding than the subsidies and there is no danger, that in case of lack of money will not be provided to these companies. Using tax credits can only support those companies, that are profitable and competitive. Many technology centers are now also part of the factory. [108]

Providers of financial support for science and research

- Grant Agency of CR
- Technology Agency of CR
- Ministry
- Masaryk University
- Private Foundation (Hlávka Foundation, Research Endowment Fund of Anna and Jaroslav Krejci, The Jan Hus Educational Foundation) [90]

Cooperation between universities and enterprises in Czech Republic is the weakest of all OECD countries. Technology Agency of CR therefore prepared an eight-year program, which will support up to 70 percent of the budget joint projects of scientific teams and companies. In Czech Republic starts largest ever government program to link business and science. Eight-year program called the Competence Centres get from the state budget a total of six billion. [86]

5. The results of the dissertation with the introduction of new knowledge

5.1 Foundations of this research and an introduction of used methods

5.1.1. Foundations of this research

Science-based industrial parks have been recognized as an effective way of promoting technology development, urban renewal, and economic growth. However, little has been done in discussing the selection strategy of high-tech industries to locate in such a park, see e.g. [18]. However, each science park (SP) is a unique system [17]. It is therefore prohibitively difficult to use traditional methods of analysis e.g. statistical analysis, which require relatively extensive input information [19]. A qualitative description is information non intensive. It is based on three values only – positive, zero, negative (increasing, constant, decreasing) [21].

Qualitative modelling is suitable for such poorly known and complex systems as Science Parks SPs. Knowledge items of qualitative nature, e.g. if productivity goes up, then profit does not decrease, are often the only available SP information , see e.g. [59]. Sets of such knowledge items are transferred into equationless models. SP models incorporate variables of different nature and different time behaviours.

Analysis/Optimization of ill-known, nonlinear, multidimensional system (INMS) as Science Park (SP) is a difficult task. The reason is, that available information is vague, sparse and partially inconsistent, therefore it is difficult to develop meaningful and sufficiently accurate models of any unsteady state SP behaviours. Qualitative quantification of time derivatives, increasing, constant, decreasing, is information non-intensive, as it is based on qualitative values only. Qualitative models can be used to generate all possible dynamic behaviours (qualitative trends/scenarios). The scenarios can be screened against the prescribed trends, maximization or minimization, of objective functions to identify all possible ways of achieving the optimal results.

The benefits of Science Parks (SPs) and similar facilities, are well known and relatively well documented, see e.g. [11]. However, formal models of SPs, which are inevitable for any application of Operational Research, e.g. Decision support algorithms, forecasts etc., exist just for very few specific tasks [57]. The main reasons, why it is so difficult to develop good models of SPs are typical for any complex systems namely: Uniqueness, Multidimensionality, Interdisciplinary nature of the problem under study [51]. Any forecast related to a SP is therefore inevitably problematic, see e.g. [54] [38].

The Set of Heuristics

The available published papers can be used to identify useful heuristics, which can be confronted with heuristics suggested by the team of experts. The following heurists are, directly or indirectly, mentioned in the following papers [17] [46]. Potential useful set of heuristics, which can be used as a nucleus for the first round ofdiscussions among experts is:

- Appropriate proximity between growth of firms and facilities is positively correlated to purported interaction.
- The formal networks among off-park facilities must be supported by a higher number of contractual relations than on-park facilities.
- Formal contracts among growth firms are more independent to distances, than informal contracts.
- The entrepreneurial environment of on-park firms support growth and performance better, than off-park firms.
- Younger firms are more dependent for their growth on informal interaction than older firms, that have developed their necessary network for interaction.
- Growth on single site location is more likely to occur among off-park entities than on park entities.

Amirahmadi and Sa [8] point out the following six factors, that were important in Silicon Valley's success:

- availability of technical expertise
- availability of existing infrastructure
- availability of venture capital
- job mobility
- information exchange networks
- spin-offs from existing utilities

The extent to which Science Parks can help to overcome these constraints depends partly on the quality of the on-site management resources, and partly on access to appropriate sources of equity and loan funds.
The following two papers [44] [45] are very useful to interpret SPs as systems.

<u>The following characteristics could be extracted from the papers:</u>

- Factor (input) conditions (i.e., natural resources, human resources, capital resources, the physical infrastructure, the administrative infrastructure, the information infrastructure, the scientific and technological infrastructure)
- Demand conditions (i.e., the local demand, the future expected local demand, the maturity of local customers, and the local demand, that could be globalized)
- Firm strategies and rivalry conditions (a local context, that encourages appropriate forms of investment and sustained upgrading and vigorous competition among locally based rivals.)
- The related and supporting industries (i.e., the existing capability, local suppliers and the existing industrial competition).

Additional source of published knowledge items is [27]. The following summary of important SP features is:

(1) Factor (input) conditions

(a) High quality of human resources, especially scientific, technical and managerial personnel

(b) Strong basic research infrastructure in universities

(c) High quality information infrastructure

(d) An ample supply of risk capital

(2) Demand conditions,

(a) The demand and the maturity of local customers

(b) The future expected local demand

(3) Context for firm strategy and rivalry

(a) A local context, that encourages investment in innovation-related activity

(b) Vigorous competition among locally based rivals

(4) Related and supporting industries

(a) The capability of local suppliers and related companies

(b) Presence of clusters instead of isolated industries

This disertation takes into consideration the follwoing basic susbystems:

- Human resources (HR)
- Technological resource (TR)
- Investment environment (IE)
- Market development (MD)

This is very similar to the set of subsystems publisehd in [36]:

- Human resources
- Technology
- Money
- Market

Qualitative Models

Human experts, especially at the very beginning of any investigation, do not use mathematical models as the basic framework for their reasoning [55]. Experts draw heavily on knowledge represented by common-sense in evaluating a situation [25] [13]. Numbers are not the only quantifiers.

A trend forecast can be downgraded to a choice of the following descriptions:

Increasing, Constant, Decreasing

If the available set of knowledge items does not allow trend forecasts, then nothing can be predicted. In other words, the trend forecast is the least information intensive, see e.g. [25] A certain knowledge/information threshold must be reached to make correct trend evaluations.

Multidimensional, interdisciplinary, difficult to observe and consequently difficult to quantify systems are prohibitively difficult to model. [30] Modern computers are extremely powerful tools, but their contribution to solving complex problems using common sense has been practically very small. [42] [6]

The main reason, why SP models development is a prohibitively difficult task is the well known information shortage. There are many different papers dealing with this aspects, e.g. [22] [14]. Unfortunately there are no recommendations how to model SPs under conditions of sever information shortage.

This shortage can be eliminated just by additional information sources. There are two ways how to eliminate this shortage:

- additional measurements/observations, this is usually time consuming and costly
- utilisation of such information items, which cannot be treated by conventional formal tools.

Optimization of poorly-known, nonlinear, multidimensional systems as Science Park (SP) is also very dificult. The reason is the same - available information is vague, sparse and heavily inconsistent. This makes any analysis especially difficult if unsteady state behaviours of SPs are studied. The information shortage has the same reason as any study of a prohibitively complex system, see e.g. [11] [23] [32] [49]

There are well-established methods of Multi-Objective Optimization, see e.g. [20] [56]. However, results of the Multi-Objective Optimization are as good as the used mathematical models. Ill-known, nonlinear, multidimensional system (INMS) are such systems, which are by their very nature, difficult to measure/observe, see e.g. [33] [34]. However, even well known systems must be treated, rather often, as INMS during early stages of projects and/or under time pressure to make decisions etc., see e.g. [20] [12] Science Parks (SPs) are typical INMS.

This study deals with models based on such information items, which cannot be studied by traditional quantitative methods as e.g. statistics. For example the following knowledge item cannot be incorporated into a statistical analysis:

If the governmental investment into research X is increasing, then there is a positive upper limit for the productivity of hi tech companies Y.

The given knowledge items can be formalised by the following two equations:

- The first derivative of Y with respect X is positive
- The second derivative of Y with respect X is negative

A set of all possible unsteady state behaviours of a SP under study is used to support different decision making tasks.

5.1.2 Introduction of used methods - tutorial introduction

Qualitative Models

To understand the following text a prior knowledge of qualitative modelling is not needed, however it may be helpful. A philosophical-logical background can be found in [59]. An introduction to qualitative modelling is presented.

Qualitative models are used routinely to solve selected tasks mentioned in different PhD thesis, see e.g. [50] [60]. The following descriptions of qualitative models theory is used in similar way as in these thesis.

Qualitative models are based just on the following quantifiers:

Values:	Positive	Zero	Negative	Anything	
Derivatives:	Increasing	Constant	Decreasing	Any direction	(1)
Symbol:	+	0	-	*	

A qualitative solution of a qualitative model is specified if all its n qualitative variables,

$$X_1, X_2, ...Xn \tag{2}$$

are described by a sequence of qualitative triplets, for details see [59]:

$$(X_1, DX_1, DDX_1), (X_2, DX_2, DDX_2),\ldots(Xn, DXn, DDXn), \tag{3}$$

where Xi is the i-th variable and DXi and DDXi are the first qualitative and second qualitative derivations with respect to t (which is usually time). Higher derivatives are not considered. They are not known if the INMS are studied.

A qualitative model has m qualitative scenarios. The j-th qualitative scenario is the n-triplet:

$$(X_1, DX_1, DDX_1), (X_2, DX_2, DDX_2),\ldots (Xn, DXn, DDXn)j, \tag{4}$$

where j = 1, 2, …, m.

A typical example of a qualitative knowledge item can be formalized by a certain simple relation between two variables X and Y. Six of them are given in Fig. 6. The Fig. 6 gives examples of six equationless relations. Each graph represents a certain shape and not numerical values. This is the reason, why the given graphs in Fig. 6 are suitable to formalise such non-numerical information items, which have no forms of traditional equations.

The given shapes do not cover e.g. minimum/qualitative valley or maximum/qualitative hill. However, e.g. a sequence of the shape 23 followed by the shape 26 represents a qualitative maximum.

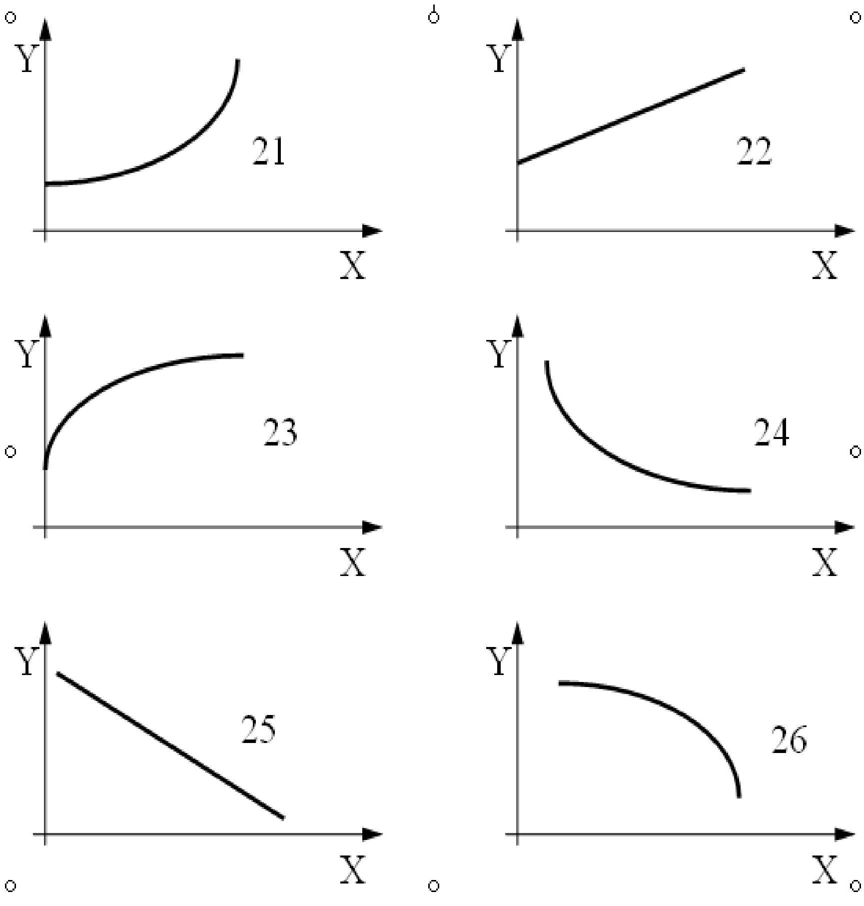


Fig. 6 - Examples of pair wise qualitative relations [59]

All pairwise relations X, Y are qualitative. It means, that nothing is qualitatively known. For example the relation 22 indicates that:

- The relation is increasing
- there is a linear relationship between Y and X
- If X = 0 then Y is positive.

all three above given knowledge items are qualitative.

However, nobody knows e.g. the numerical value of the slope. It is clear, that the slope is positive and this is all.

There are such qualitative relations, which are known so vaguely, that the second derivative is unknown (unpredictable) and therefore the following description is used to characterize them:

If X is increasing, then Y is increasing
If X is decreasing, then Y is decreasing
If X is decreasing, then Y is increasing
If X is increasing, then Y is decreasing

In other words, the first qualitative derivatives are related as follows:

DX = DY	directly proportional relation	(+)	(5)
DX = -DY	indirectly proportional relations	(-)	(6)

Let set S(m, n) of m qualitative n-dimensional scenarios (4)

S(m, n) (7)
j = 1, 2, …, m.

be a solution of a qualitative n dimensional model M

M(r, n) (8)

where r is the number of its equationless relations.

It is not the goal of this disertation to study the algorithm how to solve qualitative models. It is a combinatorial problem. The most trivial algorithm is based on systematic confrontation of all possible scenarios and the model itself. The following simple set of equationless relations (8) is a model M(2, 3) and is used as a tutorial explanation:

	Shape	X	Y	
1	22 (see Fig. 1)	X_1	X_2	(9)
2	26 (see Fig. 1)	X_3	X_2	

An algorithm, which can be used to solve the model (9) is based on pruning of a specially generated tree of combinations. It is not the goal of this disertation to describe an optimal combinatorial algorithm, as it is a purely combinatorial task.

There are 3 x 3 x 3 = 27 different one dimensional scenarios (X, DX, DDX) as each item of the triplet can have three values (1). There are (27) n different n dimensional scenarios. Each scenario must be either accepted as a solution of a model, see e.g. (9) or rejected. To simplify the problem let us suppose, that all three variables X_1, X_2 and X_3 are positive. For example X_1 is a management qualification and this is always positive. Therefore the following triple is used (+, DX_1, DDX_1).

Another simplification is, that the second derivative is ignored. It means, that just the following triplet is used (+, DX_1, Ignore). If the second derivatives are ignored, then the model (9) is simplified as follows, see Fig. 6:

1 If X_1 is increasing then X_2 is increasing
If X_1 is decreasing then X_2 is decreasing
If X_2 is increasing then X_1 is increasing
If X_2 is decreasing then X_1 is decreasing
2 If X_3 is increasing then X_2 is decreasing (10)
If X_3 is decreasing then X_2 is increasing
If X_2 is increasing then X_3 is decreasing
If X_2 is decreasing then X_3 is increasing

This simple model can be used to accept or reject two following scenarios:

Scenario	X_1	X_2	X_3	
1	(+, +, Ignore),	(+, +, Ignore),	(+, +, Ignore)	(11)
2	(+, -, Ignore),	(+, -, Ignore),	(+, +, Ignore)	

The first scenario presupposes, that the variable X_3 is increasing as its first derivative is positive. If X_3 is increasing, then X_2 is decreasing, see the simplified model. This is not possible as the first scenario gives DX_2 as negative. Therefore the first scenario is rejected. The second scenario is accepted using an additional conditional statement namely, if X_2 is decreasing, then X_1 is decreasing, see the simplified model.

If the second derivatives are taken into consideration, then the used algorithm is much more complicated. For details see [59].

The model (9) has 13 scenarios S (13, 3); (3)) as its solution:

	X_1	X_2	X_3	
1	+++	+++	+--	
2	++0	++0	+--	
3	++-	++-	+-+	
4	++-	++-	+-0	
5	++-	++-	+--	
6	+0+	+0+	+0-	
7	+00	+00	+00	(12)
8	+0-	+0-	+0+	
9	+-+	+-+	++-	
10	+-0	+-0	++-	
11	+--	+--	+++	
12	+--	+--	++0	
13	+--	+--	++-	

Unsteady State Qualitative Models

Unsteady SPs models are based on the first and second derivatives

DX	the first qualitative derivative	
DDX	the second qualitative derivative	(13)

It is possible to use higher derivatives to make the model more accurate. However, SP knowledge is so limited, that the 3rd and higher derivatives are not available. Rather often the second derivatives are not known. [41]

Fig. 7 reflects periodic changes of a variable X_1. If X_1 is e.g. profitability, then DX_1 indicates profitability changes (growing, declining or constant) and DDX_1 indicates, what is happening to the rate of change in profitability.

Precise quantitative function

$$X_1 = f(\text{time}) \tag{14}$$

is not known. What is known is, that the variable X_1 is rising, staying constant or decreasing at an unknown rate of change. Fig. 7 gives a qualitative description of an oscillation process. The corresponding scenarios are given there.

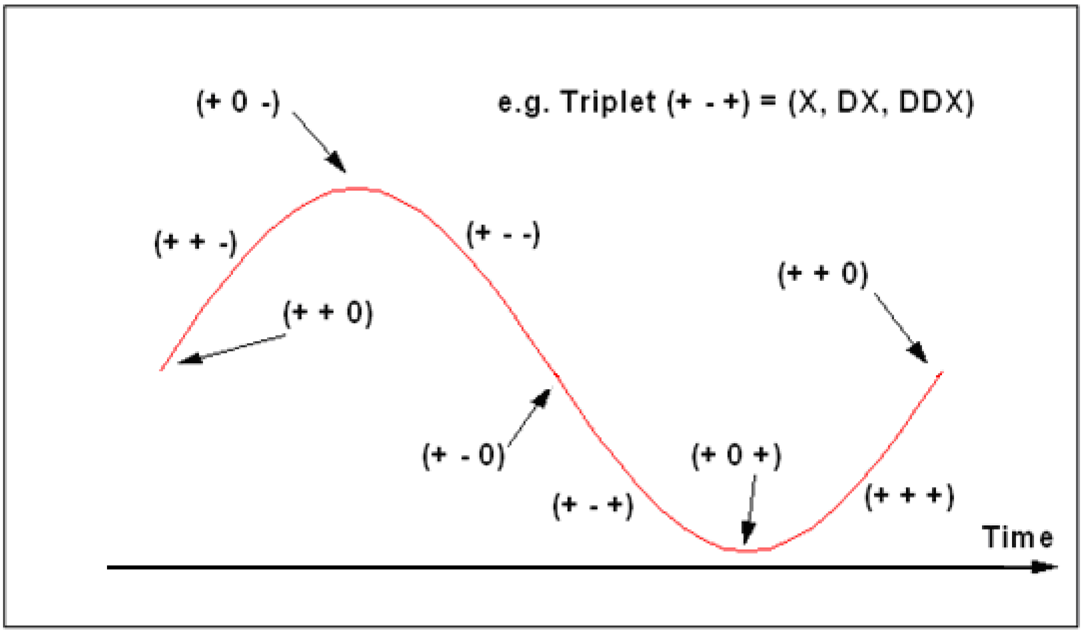


Fig. 7 - Qualitative one dimensional time record

A simple algorithm can evaluate all possible transitions among the set of one dimensional scenario. One-dimensional transitions are based on the list of all possible one-dimensional transitions, see Table 7. This table is not a dogma, it could be modified on ad hoc basis. The only requirement is, that the transitions must reflect common sense reasoning or more specifically a feeling of an expert, who uses the corresponding computer program.

Therefore there could be several different tables of one-dimensional transitions. Multidimensional transitions must satisfy the Table 7 for n one-dimensional transitions.

Table 7 - Table of all one dimensional transitions [23]

	From	To	Or	Or	Or	Or	Or	Or
No.	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	+ + +	+ + 0						
2	+ + 0	+ + +	+ + -					
3	+ + -	+ + 0	+ 0 -	+ 0 0				
4	+ 0 +	+ + +						
5	+ 0 0	+ + +	+ - -					
6	+ 0 -	+ - -						
7	+ - +	+ - 0	+ 0 +	+ 0 0	0 - +	0 0 +	0 0 0	0 - 0
8	+ - 0	+ - +	+ - -	0 - 0				
9	+ - -	+ - 0	0 - -	0 - 0				
10	0 + +	+ + 0	+ + -	+ + +				
11	0 + 0	+ + 0	+ + -	+ + +				
12	0 + -	+ + -						
13	0 0 +	+ + +						
14	0 0 0	+ + +	- - -					
15	0 0 -	- - -						
16	0 - +	- - +						
17	0 - 0	- - 0	- - +	- - -				
18	0 - -	- - 0	- - +	- - -				
19	- + +	- + 0	0 + +	0 + 0				
20	- + 0	- + -	- + +	0 + 0				
21	- + -	- + 0	- 0 -	- 0 0	0 + -	0 0 -	0 0 0	0 + 0
22	- 0 +	- + +						
23	- 0 0	- + +	- - -					
24	- 0 -	- - -						
25	- - +	- - 0	- 0 +	- 0 0				
26	- - 0	- - -	- - +					
27	- - -	- - 0						

An oriented graph is commonly used to represent graphically the set of all transitions. If it is possible to transfer the r-th scenario into the s-the scenario, then an oriented arc represents the corresponding transition from the node r to the node s. A simple example of a sequence of one dimensional transition is given in Fig. 7.

$$(++-) \quad \rightarrow \quad (+0-) \quad \rightarrow \quad (+--) \qquad (15)$$

Transitions shown in Fig. 7 correspond to transitions in Table 7. (e.g. transition 3b is row 3, column b).

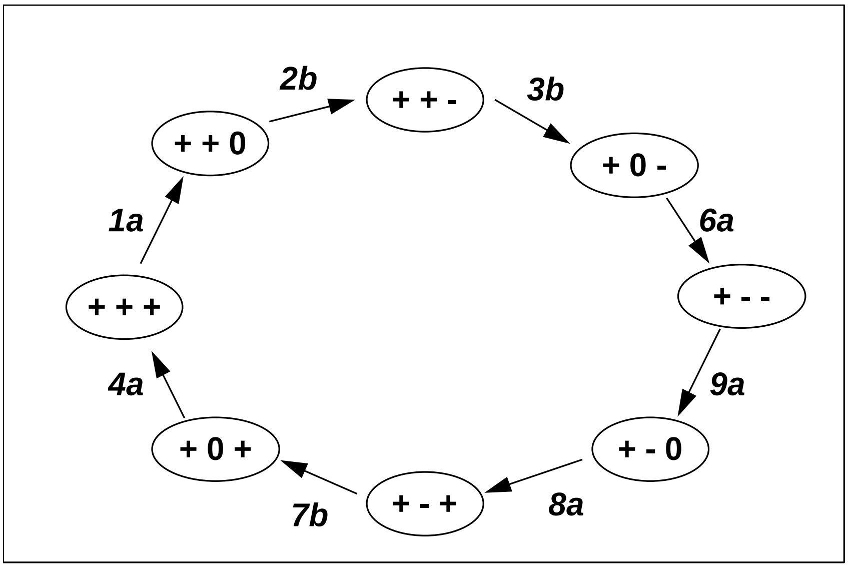


Fig. 8 Qualitative representation of the quantitative record given in Fig. 7.

Qualitative Transitions

Unsteady state behaviours of an INMS can be described by a time sequence of its scenarios. A transitional graph gives all possible unsteady state behaviours. If each scenario is represented by a node and all transitions are graphically represented by oriented arks between corresponding pairs of scenarios, the result is an oriented graph of all possible transitions. Any time behaviour of the INMS can be characterized as a path in the transition graph.

A complete set of all possible one dimensional transitions is given in Table 7.

The third line of Tab. 7 indicates, that it is possible to transfer the triplet (+ + -) into the triplet (+ 0 -). This transition is not the only possible. There are two more possible transitions. Fig. 7 gives a qualitative description of an oscillation using the one dimensional triplets n = 1 (4).

A transitional graph G is an oriented graph. Its nodes are the set of scenarios S and oriented arcs are the transitions T:

$$G(S, T) \qquad (16)$$

However, the set of transitions T can be easily generated by the corresponding set of scenarios S using Tab. 7.

A set of three dimensional scenarios (12) generates the following transitional graph.

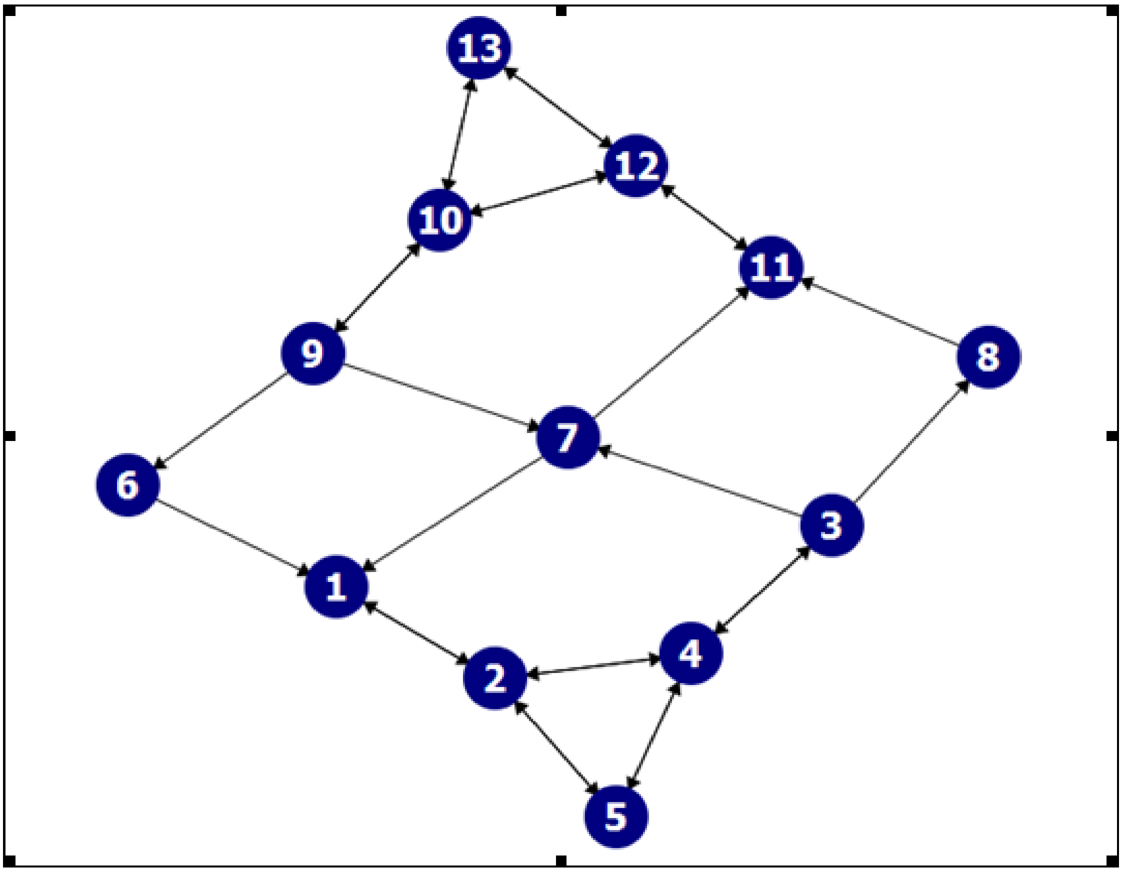


Fig. 9 - Transitional graph

The graph is a human friendly interpretation of all possible dynamic behaviours. The graph gives all possible qualitative sequences of scenarios, which represent all possible dynamic behaviours.

Let us suppose, that the third variable X3 (12) is an objective function, which must be maximized using the variables X1 and X2. A set of quantitative observations is done. Its qualitative interpretation of the experimental results corresponds to the first scenario (12). However, the results of observations confirmed, that the objective function X3 is decreasing more and more rapidly DX3 = -, DDX3 = -. The scenario 11 (12) is the best possible as it increases the objective function more and more rapidly DX3 = +, DDX3 = +. Fig. 9 indicates, that there are several paths how to reach the node 11 from node 1.

Two short paths are:

$$1 \rightarrow 2 \rightarrow 4 \rightarrow 3 \rightarrow 7 \rightarrow 11 \qquad (17)$$
$$1 \rightarrow 2 \rightarrow 4 \rightarrow 3 \rightarrow 8 \rightarrow 11$$

The following time sequence of scenarios is the detailed description of the first path:

	X_1	X_2	X_3	
1	+++	+++	+--	
2	++0	++0	+--	
4	++-	++-	+-0	(18)
3	++-	++-	+-+	
7	+00	+00	+00	
11	+--	+--	+++	

If both variables X_1, X_2 are under control of a decision maker, then it would be easy to move from the first scenario to the scenario No. 11. However, if e.g. variable X_2 is not controlled by a decision maker, then much more complex problem must be solved. However, even this problem is fully described by the graph in Fig. 9.

Qualitative Multi-Objective Optimization

Let us suppose, that there are two independent variables X1, X2 and two objective functions Q1, Q2. Both objective functions must be maximized because of their nature:

Max Q1 (19)
Max Q2

There is a vector F of constraints represented by a set of equationless relations:

$$F(X1, X2, Q1, Q2) = 0 \qquad (20)$$

Let the qualitative model (18) have the following set of three scenarios:

	X1	X2	Q1	Q2
1	+++	+++	+--	+--

2	++-	+--	+++	+--	(21)
3	+--	+-+	+-+	+++	

Therefore the first qualitative solution is totally unacceptable, see (19), because both objective functions decrease if independent variables X1 and X2 follow the qualitative pattern given in (21). Therefore the qualitative behaviour of independent variables X1 and X2

	X1	X2	
1	+++	+++	(22)

is bad with respect to the maximization of two objective functions Q1 and Q2. If there would be a set of scenarios, which contain for example, the following solution,

X1	X2	Q1	Q2	(23)
++-	+-0	+++	+++	

then the scenario (23) is highly desirable, because this scenario maximizes both objective functions in the best possible way i.e. both second derivatives are positive.

Following study was consulted with heterogenous team of experts, among whom were those representatives:

1) Economists
2) Methodics from regional councils
3) Representatives of the ministry of Industry and Trade
4) Representatives of the Ministry of Education Youth and Sports
5) Representative of University of Technology, Faculty of Business and Management

5.2 Solving the research problem:

The following studies are submitted for publication, see [47] [48] [53]. The submitted papers must be short and concise to increase their chance of being accepted for publication. This dissertation gives me fair chance to publish additional details.

To demonstrate the flexibility of different interpretatinos of SPs slow and fast SP models are studied. A set of 17 slow qualitative equationless relations, among 11 slow variables (e.g. Quality of R&D engineers, Supply of qualified outside personnel ect.) together with a set of 14 fast qualitative equationless relations, among 10 fast variables (e.g., Cooperation between industries and academics, Circulation of industry information ect.) is studied. The model's solutions i.e. set of slow and fast scenarios and transitions among them, are presented in this study in full details.

Team of experts identified two sets of relevant SP variables. The first set is used to characterize variables of slow SP changes and the second one variables of fast SP changes. Variables of slow and fast changes are identified on ad hoc bases and there is not a generally applicable rule how to assign a specific variable to either slow or fast set. The following example is just one alternative:

5.2.1 Slow Dynamic Set

Human resource

- Supply of qualified outside personnel SQP
- Human brain cultivation organizations HBC
- Quality of R&D engineers QRD

Technology resource

- Quality of research institution QRI
- Quality of enterprises QE
- Occasion for enterprises cooperating OEC (24)

Investment environment

- Regional development outlook RDO
- Living utilities LU

Market development

- Competition status CS
- Completion of supply chain CSC
- Prospects of industries PI

5.2.2 Fast Dynamic Set

Human resource

• New jobs creation	NJC	
• Incubator resources	IR	

Technology resource

• Cooperation between industries and academics	CIA	
• Circulation of industry information	CII	

Investment environment

• Scale of industries	SI	(25)
• Incentives for investment	II	
• Operation costs	OC	

Market development

• Benefit of economies of scale	BES	
• Bargaining power	BP	
• Reputation	RE	

A simple common sense analysis identifies an obvious fact, that many of the qualitative relations among variables (24, 25) are ad hoc heuristic valid just for a specific SP currently under study. For example, it is not possible to guarantee, that the increase of RDO (Regional development outlook, see (24)) always improves LU. If there is a shortage of flats LU (suitable Living Utilities), then the ad hoc relation could be:

if RDO increases, then LU decreases.

It makes no sense to integrate slow and fast variables into one qualitative model as the time horizons are different. No attempts were made to quantify the corresponding time intervals (days, months, years) as it is an ad hoc task.

Qualitative adhoc SP models are analyzed. Each model has subset of relations within the following subset of variables, see (24, 25):

- Human resource
- Technology resource
- Investment environment (26)
- Market development

and additional relations, which link variables in between the different subsets (26). The following slow and fast models are based exclusively on qualitative proportionalities (+) and (-), see (5, 6). In other words just the first derivatives are taken into consideration. It means, that the results are based on the first derivatives as well.

5.2.3 Slow Model

Relation inside the subsets of variables (24)

-	SQP	HBC
+	HBC	QRD
+	QRI	QE
+	QE	OEC
-	RDO	LU
+	PI	CSC
+	PI	CS

Relations between variables of different subsets (26) (27)

+	HBC	CS
+	QRD	CS
+	HBC	QRI
-	SQP	OEC
+	QRI	QRD
+	PI	OEC

5.2.4 Fast Model

Relation inside the subsets of variables (25)

+	NJC	IR
+	CIA	CII
-	SI	II
+	BES	RE

+	BES	BP

Relations between variables of different subsets (26) (28)

+	RE	NJC
+	BES	IR
+	CIA	RE
-	RE	OC
+	CIA	IR

There is nine scenarios, i.e. m = 9, see (4) for slow and fast set. There are 10 variables for the fast scenarios and 11 variables for slow scenario.

Fast scenarios based on first derivation:

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	++*	++*	++*	++*	++*	+-*	++*	++*	++*	+-*	
2	++*	++*	++*	++*	+0*	+0*	++*	++*	++*	+-*	
3	++*	++*	++*	++*	+-*	++*	++*	++*	++*	+-*	
4	+0*	+0*	+0*	+0*	++*	+-*	+0*	+0*	+0*	+0*	
5	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	(29)
6	+0*	+0*	+0*	+0*	+-*	++*	+0*	+0*	+0*	+0*	
7	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	+-*	++*	
8	+-*	+-*	+-*	+-*	+0*	+0*	+-*	+-*	+-*	++*	
9	+-*	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	++*	

Slow scenarios based on first derivation:

	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	PI	
1	++*	+-*	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	+-*	
2	++*	+-*	+-*	+-*	+-*	+-*	+0*	+0*	+-*	+-*	+-*	
3	++*	+-*	+-*	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	
4	+0*	+0*	+0*	+0*	+0*	+0*	++*	+-*	+0*	+0*	+0*	
5	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	(30)
6	+0*	+0*	+0*	+0*	+0*	+0*	+-*	++*	+0*	+0*	+0*	
7	+-*	++*	++*	++*	++*	++*	++*	+-*	++*	++*	++*	
8	+-*	++*	++*	++*	++*	++*	+0*	+0*	++*	++*	++*	
9	+-*	++*	++*	++*	++*	++*	+-*	++*	++*	++*	++*	

Where * means ignore. Therefore the second derivatives are ignored; see the triplets (4).

Both fifth scenarios (29, 30) are the steady state scenarios as all first derivatives are equal to zero. The first fast scenario indicates, that II, OC are decreasing and NJC, IR, CIA, CII, SI, BES, BP, RE are increasing. The first slow scenario indicates, that SQP, RDO are increasing and the rest of variables is decreasing.

However it seems, that those models (27, 28) include only few restrictions and the fast and slow scenarios consist of all the possible combinations of + 0 -. It is an example of free models (27, 28), which generates scenarios, that doesn't have to happen in reality.

5.2.5 Slow model based on the first derivative

Relation inside the subsets of variables (24)

-	SQP	HBC
+	HBC	QRD
+	QRI	QE
+	QE	OEC
-	RDO	LU
+	PI	CSC
+	PI	CS

Relations between variables of different subsets (26) (31)

+	SQP	RDO
+	HBC	CS
+	QRD	CS
+	HBC	QRI
-	SQP	OEC

5.2.6 Fast model based on the first derivative (conflict of opinions)

Relation within the subsets of variables (25)

+	NJC	IR	see (5)
+	CIA	CII	
-	SI	II	see (6)
+	BES	RE	

+	BES	BP	

Relations outside subset of variables (26) (32)

+	RE	NJC
+	BES	IR
+	CIA	RE
+	SI	BES
-	RE	OC
+	CIA	IR

5.2.7 Fast model based on the first derivative (conflict of opinions)

Relation within the subsets of variables (25)

+	IR	NJC	see (5)
+	CIA	CII	
-	SI	II	see (6)
+	BES	RE	
+	BES	BP	

Relations outside subset of variables (26) (33)

+	RE	NJC
+	BES	IR
+	CIA	RE
+	SI	BES
-	RE	OC
+	CIA	IR

Since the models (27, 28) contained very few restrictions, they behaved freely (see combinations of + 0 - matrix (29, 30)). That is why models (31, 32) have been changed as follows:

Slow model (31): relation + SQP RDO was added to the model and relations + QRI QRD, + PI OEC were removed from the model (31).

Fast model (32, 33): + SI BES was added to the models.

There are three scenarios, i.e. m = 3, see (4) for fast and slow sets. The number of variables for the fast and slow set stays the same 10 variables for the fast model and 11 variables for slow model.

Fast Scenarios based on first derivation (32):

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	++*	++*	++*	++*	++*	+-*	++*	++*	++*	+-*	(34)
2	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	
3	+-*	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	++*	

Fast Scenarios based on first derivation (33):

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	++*	++*	++*	++*	++*	+-*	++*	++*	++*	+-*	
2	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	(35)
3	+-*	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	++*	

Because the experts opinions on whether increase of new job creation can cause increase of incubator resources or if growth of incubator resources can cause new job creation were different calculation of both variants was made.

If we look closer at the fast scenario sets (34, 35) we find no difference between them.

Let´s do one more test, where incentives for investment will be the priority.

Fast Scenarios based on first derivation:

	II	CIA	CII	IR	NJC	SI	BES	RE	BP	OC	
1	++*	+-*	+-*	+-*	+-*	+-*	+-*	+-*	+-*	++*	
2	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	(36)
3	+-*	++*	++*	++*	++*	++*	++*	++*	++*	+-*	

Where * means ignore. Therefore the second derivatives are ignored; see the triplets (4).

If the decision maker wants II to be his priority, the result of the model (32, 33) rapidly changes.

We can see, that in first scenario II and OC are increasing and all the rest of variables is decreasing.

The result of the fast set (36) could be interpreted as follows:

The first scenario is realistic for the duration of the SP realization (investment) and should be expected by the decision maker.

Because there is an increase in operation costs and decrease in all the other variables this scenario is long-term unsustainable and the decision maker will very soon look for the way out of this situation (search other business opportunities). This period comes at the time of project sustainability (i.e, the period, when the SP will be put into operation).

Slow Scenarios based on first derivation:

	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	PI	
1	++*	+-*	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	+-*	
2	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	(37)
3	+-*	++*	++*	++*	++*	++*	+-*	++*	++*	++*	++*	

Where * means ignore. Therefore the second derivatives are ignored; see the triplets (4).

The third scenario (37) shows the effect of inertia. Nevertheless, there is decrease of qualified outside personnel and decrease of regional development outlook, all the other variables will still increase.

We can see, that the result of the model (31, 32, 33) has changed in comparison with the result of model (27, 28). There is 6 scenarios less in matrix (34, 35, 36, 37), than in matrix (29, 30). The result of model (31, 32, 33) is more accurate and clearer for the decision maker.

The result of the slow set (37) could be interpreted as follows:

An increase in supply of qualified outside personnel brings increase of regional development outlook, but it will take some time before it will bring the region to increase of human brain cultivation organizations, increase number of qualified R&D engineers and quality of research institutions, quality of enterprises and cooperation between them, then the completion of supply chain will close more and region will have to start building up sufficient living utilities. When all this happens, then the prospect of industries will start increasing together with competition status of the region. At this moment there is only increase of SQP and RDO, all the rest of the variables is still decreasing.

Let us compare both results of models (27, 28) and (31, 32, 33):

Fast scenarios result comparison:

Both fast scenario sets (29, 34, 35) include steady state scenarios as all first derivatives are equal to zero. In fast set (29) it is scenario No. 5 and in fast set (34, 35) it is scenario No. 2. This particular scenario is special, because nothing changes (everything is steady state).

If we look at the first and last scenarios of set (29, 34, 35) we find out, that the scenarios are the same. In both first scenarios (29, 34, 35) incentives for investment and operation costs are decreasing and new jobs creation, incubator resources, cooperation between industries and academics, circulation of industry information, scale of industries, benefits of economies of scale, bargaining power and reputation are increasing.

Slow scenarios result comparison:

Both slow scenario sets (30, 37) include steady state scenarios as all first derivatives are equal to zero. In slow set (30) it is scenario No. 5 and in slow set (37) it is scenario No. 2. This particular scenario is special, because nothing changes (everything is steady state).

If we look at the first and last scenarios of slow set (30, 37) we find out, that the scenarios are again the same. In both first scenarios (30, 37) supply of qualified outside personnel and Regional development outlook are increasing and human brain cultivation organizations, quality of R&D engineers, quality of research institution, quality of enterprises, occasion for enterprises cooperating, living utilities, competition status, completion of supply chain and prospects of industries are decreasing.

From above mentioned it follows, that the more precise information we reflect into the fast or slow model the easier it will become to interpret generated results for the decision maker.

Let´s look at the Fast and Slow model in more detail:

Different variables within the fast model (32, 33) are controlled by managements (MAN) and government GOV. Some variables are not directly controlled as they are goals (GOA):

	Controlled by	
New jobs creation	NJC	MAN
Incubator resources	IR	MAN
Cooperation between industries and academics	CIA	GOA
Circulation of industry information	CII	MAN
Scale of industries	SI	MAN

Incentives for investment	II	GOV	(38)
Operation costs	OC	MAN	
Benefit of economies of scale	BES	MAN	
Bargaining power	BP	MAN	
Reputation	RE	MAN	

There is just one goal to be achieved/maximized namely increase the cooperation between industries and academics CIA. It means, that the first scenario (34, 35) is desirable. However to achieve this scenario a cooperation of the managements and government is inevitable.

CII	IR	NJC	SI	II	BES	RE	BP	OC	
IN	IN	IN	IN	DE	IN	IN	IN	DE	(39)
MAN	MAN	MAN	MAN	GOV	MAN	MAN	MAN	MAN	

where DE is decrease, IN is increase.

If Incubator resources IR are interpreted as a goal GOA, then two objective functions must be maximised.

CIA	IR	(40)
IN	IN	

It means, that both goals can be achieved at the same time.

Let us do the same test again, but for different goal. Now the decision maker will want to draw maximum of subsidies.

	Controlled by		
New jobs creation	NJC	MAN	
Incubator resources	IR	MAN	
Cooperation between industries and academics	CIA	MAN	
Circulation of industry information	CII	MAN	
Scale of industries	SI	MAN	
Incentives for investment	II	GOA	(41)

Operation costs	OC	MAN
Benefit of economies of scale	BES	MAN
Bargaining power	BP	MAN
Reputation	RE	MAN

There is just one goal to be achieved/maximized namely increase the incentives for investment II and not controlled by a government. It means, that the first scenario (36) is desirable. However to achieve this scenario a cooperation of the managements is inevitable.

CIA	CII	IR	NJC	SI	BES	RE	BP	OC	
DE	DE	DE	DE	DE	DE	DE	DE	IN	(42)
MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	

where DE is decrease, IN is increase.

If incubator resources IR are interpreted as a goal GOA, then two objective functions must be maximised. However, there is no such scenario, which has II and IR increasing.

II	IR	(43)
IN	DE	

It means, that both goals can not be achieved at the same time.

Different variables within the slow model (31) are controlled by government (GOV), management (MAN) and local authorities (LAU). Some variables are not directly controlled as they are goals (GOA):

	Controlled by		
Supply of qualified outside personnel	SQP	GOV	
Human brain cultivation organizations	HBC	GOV	
Quality of R&D engineers	QRD	MAN	
Quality of research institution	QRI	MAN	
Quality of enterprises	QE	MAN	
Occasion for enterprises cooperating	OEC	MAN	(44)
Regional development outlook	RDO	GOV	
Living utilities	LU	LAU	

Competition status	CS	MAN
Completion of supply chain	CSC	MAN
Prospects of industries	PI	GOA

There is just one goal to be achieved/maximised namely increase the Prospects of industries PI. It means, that the third scenario (37) is desirable. However to achieve this scenario a cooperation of the management, government and local authorities is inevitable.

SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	(45)
DE	IN	IN	IN	IN	IN	DE	IN	IN	IN	
GOV	GOV	MAN	MAN	MAN	MAN	GOV	LAU	MAN	MAN	

where DE is decrease, IN is increase.

If regional development outlook RDO is interpreted as a goal GOA and not controlled by a government, then two objective functions must be maximised. However, there is no such scenario which has RDO and PI increasing.

RDO	PI	(46)
DE	IN	

It means, that both goals can not be achieved at the same time.

The models (31, 32, 33) are based on the first derivates only and therefore the answer is based on the first derivatives as well. Rather often it is possible to identify such set of scenarios by simple common sense reasoning.

Team of experts developed the following fast and slow model, which partially incorporates additional information items based on second derivatives:

5.2.8 Fast model based partially on second derivative (conflict of opinions)

See Fig. 1	X	Y
23	NJC	IR
21	CIA	CII

25	SI	II	
23	BES	BP	
+	BES	RE	
+	RE	NJC	(47)
+	BES	IR	
+	CIA	RE	
+	SI	BES	
-	RE	OC	
+	CIA	IR	

The first four relations of the model (47) is based on the second derivatives, see Fig. 6. The first relation is represented in the model (32) just by qualitative proportionality. However the shape 23, see Fig.6 indicates, that the second qualitative derivative IR with respect to NJC is negative. This additional qualitative information item makes the model (47) much more accurate. The team of experts was not able to make the last 7 relations of the model (47) more precise.

There are 15 fast scenarios:

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	+++	+++	+++	+++	+++	+--	+++	+++	+++	+--	
2	+++	+++	+++	+++	+++	+--	+++	+++	++0	+--	
3	+++	+++	+++	+++	+++	+--	+++	+++	++-	+--	
4	++-	+++	++-	++-	++-	+-+	++-	++-	++-	+-+	
5	++-	++0	++-	++-	++-	+-+	++-	++-	++-	+-+	
6	++-	++-	++-	++-	++-	+-+	++-	++-	++-	+-+	
7	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
8	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	(48)
9	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
10	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-	
11	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-	
12	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+--	++-	
13	+--	+-+	+--	+--	+--	+++	+--	+--	+--	+++	
14	+--	+-0	+--	+--	+--	+++	+--	+--	+--	+++	
15	+--	+--	+--	+--	+--	+++	+--	+--	+--	+++	

The scenario No. 8 is the steady state scenario and it corresponds to the 2nd scenario (34) of the model (32) based on the first derivatives only. The scenarios Nos. 1 – 15 are more accurate qualitative descriptions of the first set of scenarios (34).

If we look closer to set of scenarios (48) based partially on second derivations we find out, that there is no difference between the results (34, 48) although model (47) contains more accurate information. In both fast sets (34, 48) based on the first and second derivation II and OC are decreasing in the first scenario and increasing in the last scenario. The rest of variables is increasing in the first scenario and decreasing in the last scenario (34, 48).

The advantage of the model based partially on the second qualitative derivation is, that the model itself is much more accurate and includes additional qualitative information items in comparison with the model based on first qualitative derivation, where the information is vague. The set of scenarios based on the second derivation shows in detail overview all possible situations, which can occur in reality. Moreover it is possible to convert those complete sets of fast and slow scenarios into the graph of transitions see Fig. 9. This would not be possible if we know only information based on the first qualitative derivations.

The complete graph of transitions among the set of scenarios (48) is represented by the Fig. 10. The Tab. 7 of the one dimensional transition is used.

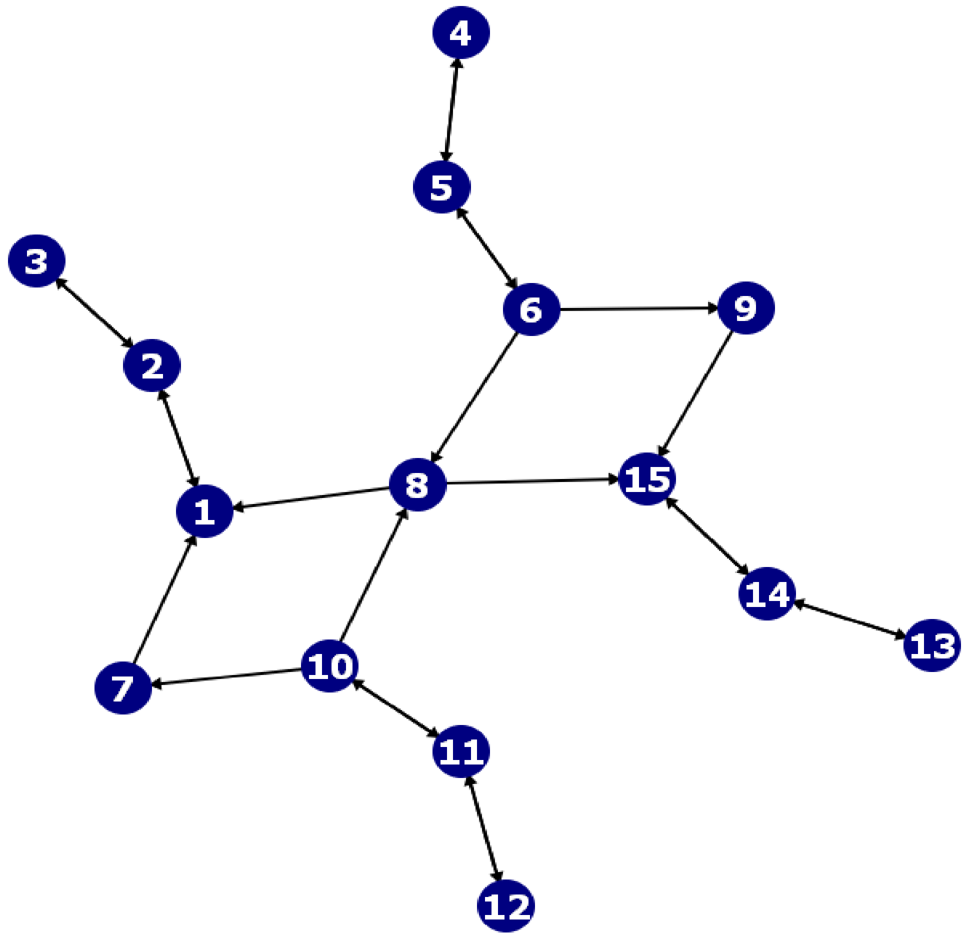


Fig. 10 - Graph of transitions among the set of scenarios (48)

The oriented graph is a human friendly interpretation of all possible SP dynamic behaviours. It means, that the graph gives all possible qualitative sequences of scenarios, which represents dynamic behaviours.

If CIA is the goal, which must be maximized, then the set of scenarios can be divided into the following subsets, see the first column of the matrix (48):

CIA	Scenario No.	
+++	1, 2, 3	
++-	4, 5, 6	
+0+	7	
+00	8	(49)
+0-	9	
+-+	10, 11, 12	

+-- 13, 14, 15

The best CIA behaviour is described by (+ + +) as it means, that CIA is increasing and the increase is higher and higher. The worst scenario is described by the triplet (+ - -), see the scenario No. 13, 14, 15 (48, Fig. 10).

The following list of possible transitions from and to the set of scenarios with CIA (+++) has four elements:

No.	From	To	
1	1	2	
2	2	1	(50)
3	2	3	
4	3	2	

If a SP is described by the scenario 13, 14, 15, then there is no way out of this bad situation, see Fig. 10. On the other hand if the SP behaviour is represented by a scenario from the set of scenarios (1, 2, 3), then a managerial decision can just transfer SP within this set. It means, that the favourable triplet (+ + +), see (48, 49), will be valid for ever irrespective of any mistakes done by managements.

To see, if there is no difference in result of the changed model (51) let´s do the test again. The model has been changed, because the group of experts had different opinion on whether increase of new job creation can cause increase of incubator resources, or if growth of incubator resources cause new job creation.

5.2.9 Fast model based partially on second derivative (conflict of opinions)

See Fig. 1	X	Y	
23	IR	NJC	
21	CIA	CII	
25	SI	II	
23	BES	BP	
+	BES	RE	
+	RE	NJC	(51)

+	BES	IR
+	CIA	RE
+	SI	BES
-	RE	OC
+	CIA	IR

There are 15 fast scenarios:

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	+++	+++	+++	+++	+++	+--	+++	+++	+++	+--	
2	+++	+++	+++	+++	+++	+--	+++	+++	++0	+--	
3	+++	+++	+++	+++	+++	+--	+++	+++	++-	+--	
4	++-	+++	++-	++-	++-	+-+	++-	++-	++-	+-+	
5	++-	++0	++-	++-	++-	+-+	++-	++-	++-	+-+	
6	++-	++-	++-	++-	++-	+-+	++-	++-	++-	+-+	
7	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	(52)
8	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	
9	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
10	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-	
11	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-	
12	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+--	++-	
13	+--	+-+	+--	+--	+--	+++	+--	+--	+--	+++	
14	+--	+-0	+--	+--	+--	+++	+--	+--	+--	+++	
15	+--	+--	+--	+--	+--	+++	+--	+--	+--	+++	

The test shows, that there is no difference for those two sets of scenarios (48, 52). It means, that both model variants are possible (23 NJC IR, 23 IR NJC) and there is no difference in the results.

All the rest of the actions stays the same see (Fig. 10, 49, 50).

Interpretation could be:

If the decision maker prefers to maximize cooperation between industries and academics, which will bring him new scientific results and innovations, than he has to expect decrease of incentives for investment and decrease of operation costs (which is always wanted). On the other hand all the rest of variables will increase. This could be good decision, but at the expense of drawing of subsidies. The decision maker will have to compromise. This could be a situation of existing and prosperous SP.

Let´s see, what happens if II is the goal, which must be maximized. The model stays the same(51).

There are 15 fast scenarios:

	II	CIA	CII	IR	NJC	SI	BES	RE	BP	OC	
1	+++	+--	+-+	+--	+--	+--	+--	+--	+--	+++	
2	+++	+--	+-0	+--	+--	+--	+--	+--	+--	+++	
3	+++	+--	+--	+--	+--	+--	+--	+--	+--	+++	
4	++-	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+-+	++-	
5	++-	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+-0	++-	
6	++-	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+--	++-	
7	+0+	+0-	+0-	+0-	+0-	+0-	+0-	+0-	+0-	+0+	
8	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	(53)
9	+0-	+0+	+0+	+0+	+0+	+0+	+0+	+0+	+0+	+0-	
10	+-+	++-	+++	++-	++-	++-	++-	++-	++-	+-+	
11	+-+	++-	++0	++-	++-	++-	++-	++-	++-	+-+	
12	+-+	++-	++-	++-	++-	++-	++-	++-	++-	+-+	
13	+--	+++	+++	+++	+++	+++	+++	+++	+++	+--	
14	+--	+++	+++	+++	+++	+++	+++	+++	++0	+--	
15	+--	+++	+++	+++	+++	+++	+++	+++	++-	+--	

The scenario No. 8 is again the steady state scenario.

If we look closer to set (53) we find out, that there is a difference between the results (48, 52, 53). In set of scenarios (48, 52) II and OC were decreasing, but in set of scenarios (53) they are both increasing. The rest of the variables behave in reverse except for CII, see (48, 52, 53).

The complete graph of transitions among the set of scenarios (53) is represented by the Fig. 11. The Tab. 7 of the one dimensional transition is used.

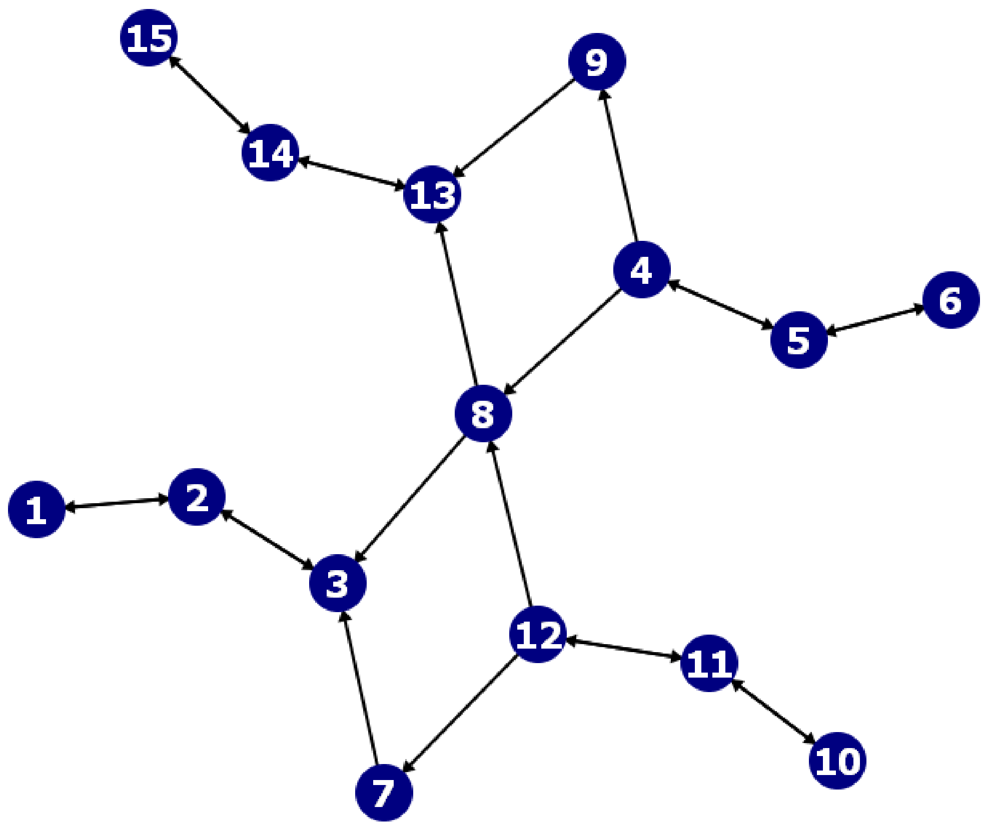


Fig. 11 - Graph of transitions among the set of scenarios (53)

The curent goal is II, which must be maximized. This variable II is directly controlled by government, with all consequences. II meaningfull support from the goventmnet is enavitable. It means, that the set of scenarios can be divided into the following subsets, see the first column of the matrix (53):

II	Scenario No.	
+++	1, 2, 3	
++-	4, 5, 6	
+0+	7	
+00	8	(54)
+0-	9	
+-+	10, 11, 12	
+--	13, 14, 15	

The best II behaviour is described by (+ + +) as it means, that II is increasing and the increase is higher and higher. The worst scenario is described by the triplet (+ - -), see the scenario No. 13, 14, 15 (53, Fig. 11).

The following list of possible transitions from and to the set of scenarios with II (+++) has four elements:

No.	From	To	
1	1	2	
2	2	1	(55)
3	2	3	
4	3	2	

If a SP is described by the scenario 13, 14, 15, then there is no escape of this bad situation, see Fig. 11. On the other hand if the SP behaviour is represented by a scenario from the set of scenarios (1, 2, 3), then a integrated managerial or governmental decision is inevitable and can just transfer SP within this set. It means, that the favourable triplet (+ + +), see (53, 54), will be valid for ever irrespective of any mistakes done by managements or government.

Interpretation of the best II scenario No. 1 could be:

If the decision maker focuses all his attention on drawing subsidies, then he looses energy for establishing cooperation between industries and academics (decreasing), which also leads to decrease in incubator resources, new job creations and scale of industry, which is connected to decrease in benefits of economies of scale, bargaining power and reputation. During the granted SP realization it leads to increase in operation costs. In case of circulation of industry information the situation gradually improves. This may be due to the realization of the SP (introduction of modern technologies ect.).

Better situation could occur if compromise could be chosen. Of course it depends on decision makers financial situation and possibilities. If he has enough financial resources for co-financing of future donated SP and even he has enough money to overcome late payment of subsidies, than he can afford to choose the way of scenario No. 1 for time of project implementation. At the time, when the implementation of the SP is finished (sustainability period), there is the high time to search the way how to establish the CIA ect.

Or the decision maker makes a compromise and chooses the path of scenario No. 4

Incentives for investment will be drawn almost at the maximum possible level, gradually in longer time period (the plan of call for funds is usually announced in advance). Than cooperation between industries and academics would gradually slow its decline (improve) together with circulation of industry information, incubator resources, new job creation, scale of industry, benefits of economies of scale, bargaining power and reputation. The operation costs would be increasing, but slower.

However, the realistic transitional graphs are much more complex and more difficult to interpret. If the model (51) is slightly modified, then the number of transitions is relatively high. Just three model's (51) modifications are done:

1 if D (IR) = (+) then 23 IR NJC IR
2 if D (CIA) = (+) then 21 CIA CII CIA (56)
11 if D (CII) = (+) then M+_ CIA IR CII

The macro-instructions Nos. 1, 2 and 11 are conditional. If the first derivatives D of IR, CIA and CII are positive, then the corresponding macro-instructions (56) replace the original ones. Simple common sense reasoning indicates, that the number of scenarios for the modified model (51) will be higher. The reason is, that the macroinstructions (56) are restrictive just for a specific values of three variables and not always.
The modified model (51, 56) has 78 scenarios and 422 transitions among them.

The result of modified model (51, 56) follow:

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC
1	+++	+++	+++	+++	+++	+--	+++	+++	+++	+--
2	+++	+++	+++	+++	+++	+--	+++	+++	++0	+--
3	+++	+++	+++	+++	+++	+--	+++	+++	++-	+--
4	++-	+++	++-	++-	++-	+-+	++-	++-	++-	+-+
5	++-	++0	++-	++-	++-	+-+	++-	++-	++-	+-+
6	++-	++-	++-	++-	++-	+-+	++-	++-	++-	+-+
7	+0+	+++	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-
8	+0+	++0	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-
9	+0+	++-	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-
10	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-

11	+0+	+00	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
12	+0+	+0-	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
13	+0+	+-+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
14	+0+	+-0	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
15	+0+	+--	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
16	+00	+++	+00	+00	+00	+00	+00	+00	+00	+00	
17	+00	++0	+00	+00	+00	+00	+00	+00	+00	+00	
18	+00	++-	+00	+00	+00	+00	+00	+00	+00	+00	
19	+00	+0+	+00	+00	+00	+00	+00	+00	+00	+00	
20	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	
21	+00	+0-	+00	+00	+00	+00	+00	+00	+00	+00	
22	+00	+-+	+00	+00	+00	+00	+00	+00	+00	+00	
23	+00	+-0	+00	+00	+00	+00	+00	+00	+00	+00	
24	+00	+--	+00	+00	+00	+00	+00	+00	+00	+00	
25	+0-	+++	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
26	+0-	++0	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
27	+0-	++-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
28	+0-	+0+	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
29	+0-	+00	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
30	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
31	+0-	+-+	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
32	+0-	+-0	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	(57)
33	+0-	+--	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
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43	+-+	+0+	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-	
44	+-+	+0+	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-	

45	+-+	+0+	+-+	+-+	+-+	++-	+-+	+-+	+--	++-
46	+-+	+00	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-
47	+-+	+00	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-
48	+-+	+00	+-+	+-+	+-+	++-	+-+	+-+	+--	++-
49	+-+	+0-	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-
50	+-+	+0-	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-
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52	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-
53	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-
54	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+--	++-
55	+-+	+-0	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-
56	+-+	+-0	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-
57	+-+	+-0	+-+	+-+	+-+	++-	+-+	+-+	+--	++-
58	+-+	+--	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-
59	+-+	+--	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-
60	+-+	+--	+-+	+-+	+-+	++-	+-+	+-+	+--	++-
61	+-0	+++	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
62	+-0	++0	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
63	+-0	++-	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
64	+-0	+0+	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
65	+-0	+00	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
66	+-0	+0-	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
67	+-0	+-+	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
68	+-0	+-0	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
69	+-0	+--	+-0	+-0	+-0	++0	+-0	+-0	+--	++0
70	+--	+++	+--	+--	+--	+++	+--	+--	+--	+++
71	+--	++0	+--	+--	+--	+++	+--	+--	+--	+++
72	+--	++-	+--	+--	+--	+++	+--	+--	+--	+++
73	+--	+0+	+--	+--	+--	+++	+--	+--	+--	+++
74	+--	+00	+--	+--	+--	+++	+--	+--	+--	+++
75	+--	+0-	+--	+--	+--	+++	+--	+--	+--	+++
76	+--	+-+	+--	+--	+--	+++	+--	+--	+--	+++
77	+--	+-0	+--	+--	+--	+++	+--	+--	+--	+++
78	+--	+--	+--	+--	+--	+++	+--	+--	+--	+++

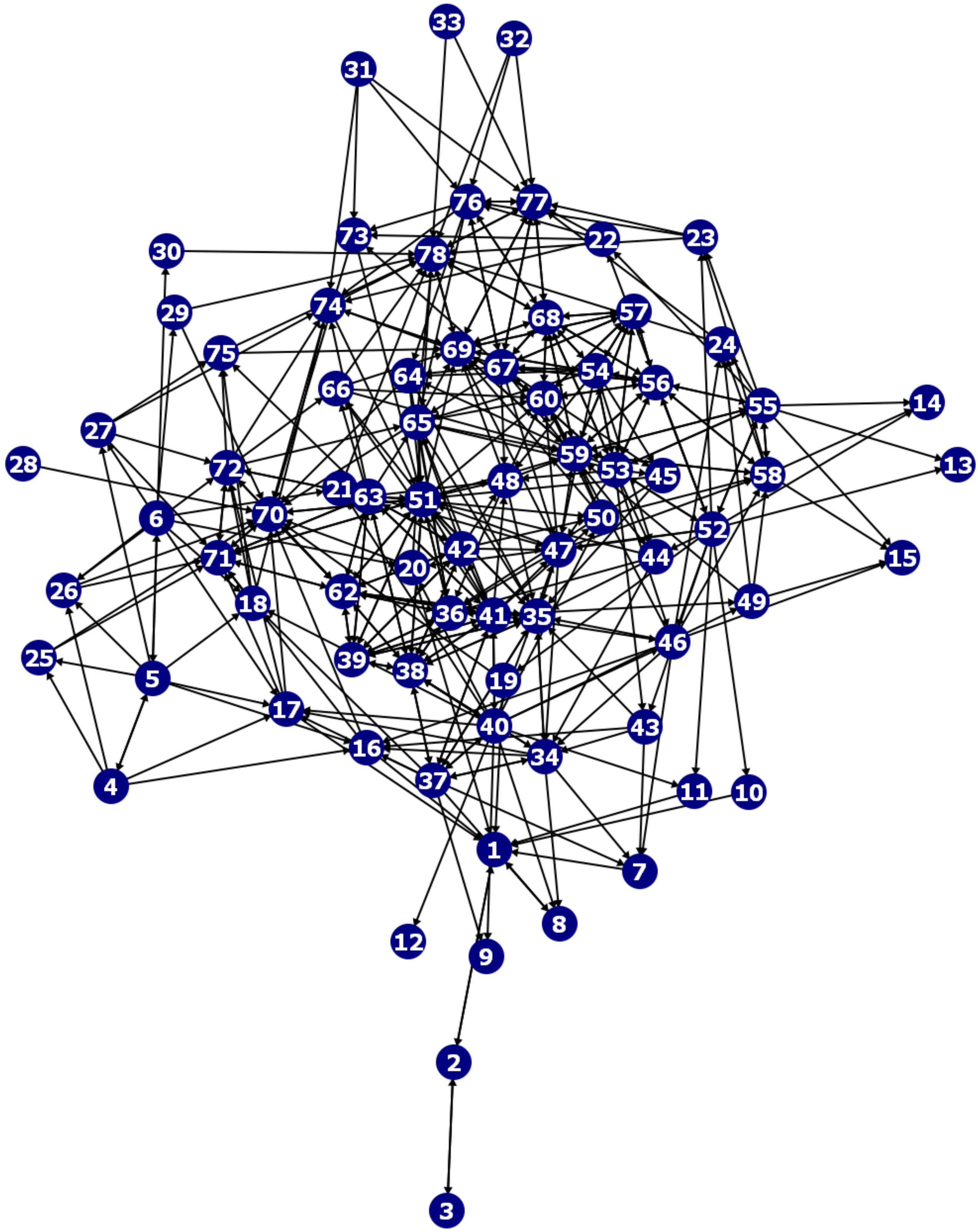

Fig. 12 Graph of transitions among the set of scenarios (57)

It means, that the graph is significantly more complex if compared with the transition graph Fig. 10. It is difficult to identify all possible oriented loops in such complex graph.

The optimal CIA triplet (+ + +) have three scenarios of the modified model (53, 56), see (57). The following list of possible transitions from and to the set of scenarios with the CIA (+ + +) has four elements.

No.	From	To	
1	1	2	
2	2	1	
3	2	3	(58)
4	3	2	

The interpretation of the set of scenarios (57) depends on the nature of the variables (25). Different variables are controlled by managements (MAN) and government GOV. Some variables are not directly controlled as they are goals (GOA):

	Controlled by		
New jobs creation	NJC	MAN	
Incubator resources	IR	MAN	
Cooperation between industries and academics	CIA	GOA	
Circulation of industry information	CII	MAN	
Scale of industries	SI	MAN	
Incentives for investment	II	GOV	(59)
Operation costs	OC	MAN	
Benefit of economies of scale	BES	MAN	
Bargaining power	BP	MAN	
Reputation	RE	MAN	

There is just one goal to be achieved/maximized namely the Cooperation between industries and academics CIA. It means, that the first scenario (57) is desirable. However to achieve this scenario a cooperation of the managements and government is inevitable.

The set of the best CIA scenarios is the set of the first three scenarios (57):

	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	+++	+++	+++	+++	+--	+++	+++	+++	+--	
2	+++	+++	+++	+++	+--	+++	+++	++0	+--	(60)
3	+++	+++	+++	+++	+--	+++	+++	++-	+--	

The set (60) can be characterised as follows**:**

CII	IR	NJC	SI	II	BES	RE	BP	OC	
↑	↑	↑	↑	↓	↑	↑	↑↓	↓	(61)
MAN	MAN	MAN	MAN	GOV	MAN	MAN	MAN	MAN	

where arrows indicate increase or decrease of the corresponding variables in the set of scenarios (60).

If Incubator resources IR is interpreted as a goal GOA, then two objective functions must be maximized. There are three scenarios, which maximizes both objective functions, see No. 1, 2, 3 in (60). There is nine scenarios, which have the worst possible triplet (+ - -), see (57), as the descriptor for both objective functions CIA and IR, namely the scenario No. 70-78.

Interpretation of the best CIA and IR scenario No. 1 could be:

If the goal of the decision maker is to increase the cooperation between industries and academics and incubator resources, then all the other variables will increase and the increase will be higher and higher accept incentives for investment and operation costs. Question will be, if the decision maker has enough financial resources to build sufficient background for the SP, because the incentives for investments will be decreasing together with operational costs. This could be the decision of the head of existing and prospering SP.

Let´s make another test, where just two modifications of model (51) are done:

1 if D (IR) = (+) then 23 IR NJC IR
2 if D (II) = (+) then 21 CIA CII II (62)

The modified model (51, 62) has 71 scenarios and 291 transitions among them.

The result of modified model (51, 62) follow:

	II	CIA	CII	IR	NJC	SI	BES	RE	BP	OC
1	+++	+--	+++	+--	+--	+--	+--	+--	+--	+++
2	+++	+--	+-+	+--	+--	+--	+--	+--	+--	+++
3	+++	+--	+-0	+--	+--	+--	+--	+--	+--	+++
4	+++	+--	+--	+--	+--	+--	+--	+--	+--	+++
5	++0	+-0	+-+	+-0	+-0	+-0	+-0	+-0	+--	++0
6	++-	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+-+	++-
7	++-	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+-0	++-
8	++-	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+--	++-
9	+0+	+0-	+++	+0-	+0-	+0-	+0-	+0-	+0-	+0+
10	+0+	+0-	++0	+0-	+0-	+0-	+0-	+0-	+0-	+0+
11	+0+	+0-	++-	+0-	+0-	+0-	+0-	+0-	+0-	+0+
12	+0+	+0-	+0+	+0-	+0-	+0-	+0-	+0-	+0-	+0+
13	+0+	+0-	+00	+0-	+0-	+0-	+0-	+0-	+0-	+0+
14	+0+	+0-	+0-	+0-	+0-	+0-	+0-	+0-	+0-	+0+
15	+0+	+0-	+-+	+0-	+0-	+0-	+0-	+0-	+0-	+0+
16	+0+	+0-	+-0	+0-	+0-	+0-	+0-	+0-	+0-	+0+
17	+0+	+0-	+--	+0-	+0-	+0-	+0-	+0-	+0-	+0+
18	+00	+00	+++	+00	+00	+00	+00	+00	+00	+00
19	+00	+00	++0	+00	+00	+00	+00	+00	+00	+00
20	+00	+00	++-	+00	+00	+00	+00	+00	+00	+00
21	+00	+00	+0+	+00	+00	+00	+00	+00	+00	+00
22	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00
23	+00	+00	+0-	+00	+00	+00	+00	+00	+00	+00
24	+00	+00	+-+	+00	+00	+00	+00	+00	+00	+00
25	+00	+00	+-0	+00	+00	+00	+00	+00	+00	+00
26	+00	+00	+--	+00	+00	+00	+00	+00	+00	+00
27	+0-	+0+	+++	+0+	+0+	+0+	+0+	+0+	+0+	+0-

28	+0-	+0+	++0	+0+	+0+	+0+	+0+	+0+	+0+	+0-	
29	+0-	+0+	++-	+0+	+0+	+0+	+0+	+0+	+0+	+0-	(63)
30	+0-	+0+	+0+	+0+	+0+	+0+	+0+	+0+	+0+	+0-	
31	+0-	+0+	+00	+0+	+0+	+0+	+0+	+0+	+0+	+0-	
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62	+--	+++	+0-	+++	+++	+++	+++	+++	++-	+--
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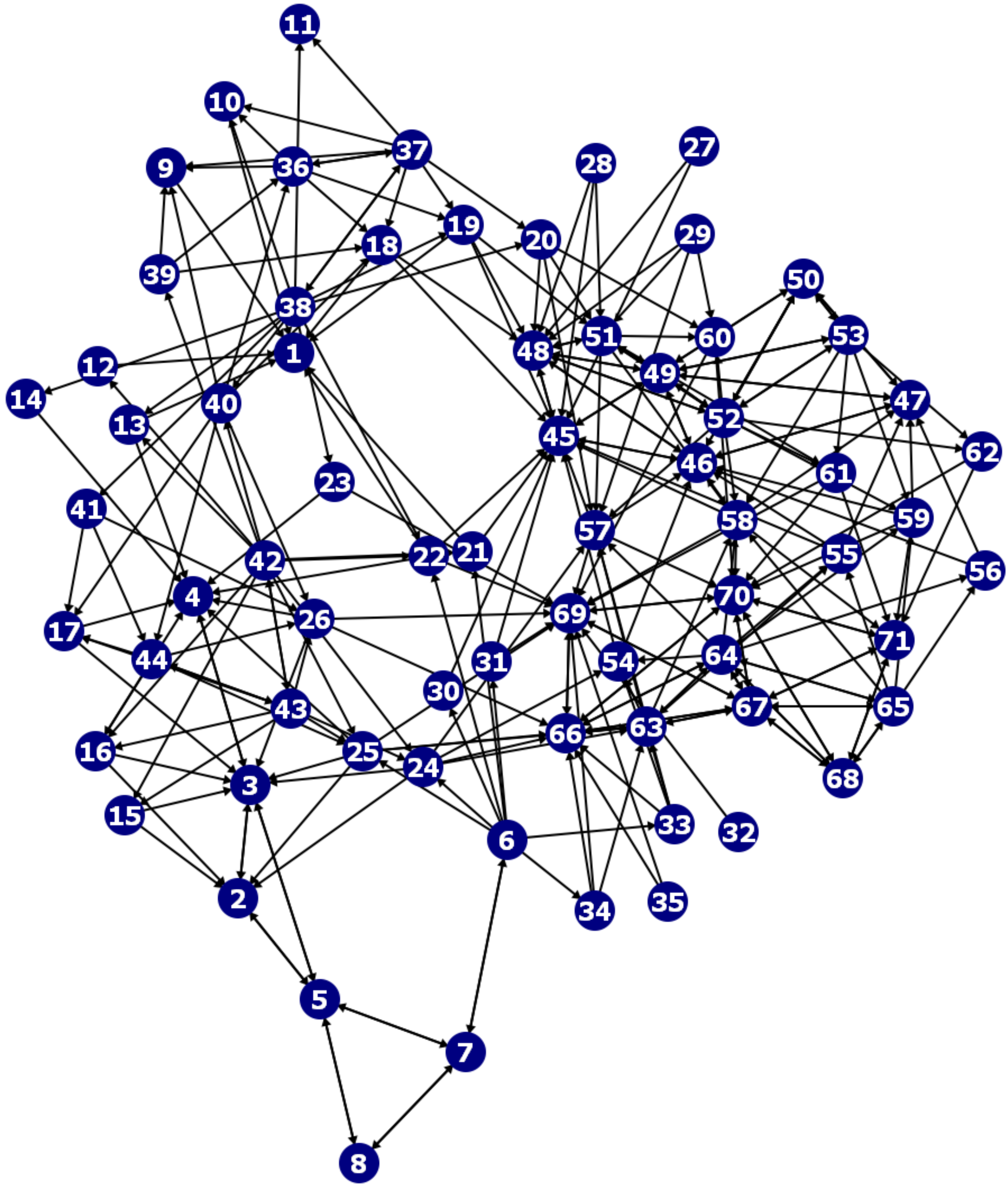

Fig. 13 Graph of transitions among the set of scenarios (63)

The optimal II triplet (+ + +) have first four scenarios of the modified model (51, 62), see set of scenarios (63). The following list of possible transitions from and to the set of scenarios with the II (+ + +) has 8 elements.

No.	From	To	
1	2	3	
2	2	5	
3	3	2	
4	3	4	
5	3	5	
6	4	3	(64)
7	5	2	
8	5	3	

It means, that the graph is significantly more complex if compared with the transition graph on Fig. 11. It is difficult to identify all possible oriented loops in such complex graph.

The interpretation of the set of scenarios (63) depends on the nature of the variables (25). Different variables are controlled by managements (MAN) and government (GOV). Some variables are not directly controlled as they are goals (GOA):

		Controlled by	
New jobs creation	NJC	MAN	
Incubator resources	IR	MAN	
Cooperation between industries and academics	CIA	MAN	
Circulation of industry information	CII	MAN	
Scale of industries	SI	MAN	
Incentives for investment	II	GOA	(65)
Operation costs	OC	MAN	
Benefit of economies of scale	BES	MAN	
Bargaining power	BP	MAN	
Reputation	RE	MAN	

There is just one goal to be achieved/maximized, namely the incentives for investment II and not controlled by the government. It means, that the first scenario (63) is desirable.

However to achieve this scenario a cooperation of the managements and government is inevitable.

The set of the best II scenarios is the set of the first four scenarios (63):

	CIA	CII	IR	NJC	SI	BES	RE	BP	OC	
1	+--	+++	+--	+--	+--	+--	+--	+--	+++	
2	+--	+-+	+--	+--	+--	+--	+--	+--	+++	
3	+--	+-0	+--	+--	+--	+--	+--	+--	+++	(66)
4	+--	+--	+--	+--	+--	+--	+--	+--	+++	

The set of scenarios (66) can be characterised as follows:

CIA	CII	IR	NJC	SI	BES	RE	BP	OC	
↓	↑↓	↓	↓	↓	↓	↓	↓	↑	(67)
MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	

where arrows indicate increase or decrease of the corresponding variables in the set of scenarios (66).

If Incubator resources IR are interpreted as a goal GOA, then two objective functions must be maximised. There is no scenario, which maximizes both objective functions, see (63, 66). There is also not the worst possible triplet, where both functions would be decreasing (+ - -), see (63).

Interpretation of the result of conditional model (51, 62) could be:

If the decision maker wants to maximize incubator resources and draw maximum of subsidies, then it seams to be an impossible dream. There is no way how to get maximum of both at the same time.

The best compromise in case the decision maker wants to draw maximum of subsidies scenario No. 1 (63, 66). This scenario shows, that II will increase together with circulation of industry information and operation costs. All the rest of variables will decrease. Almost the same situation is described in first scenario (53).

Summary of interpretation of results of modified models (51, 56) and (51, 62):

It seams to be, that those two conditions (56, 62) are given by two kind of decision makers, who are in different starting position.

Conditional model (51, 56) seem to be the decision making process of the manager of existing SP, who wants to ensure the sustainability of the SP and lead the region to further development and thus enhance its competitiveness.

The conditional model (51, 62) could reflect the decision making process of the manager, who has the ambition to implement new SP project. He needs to draw the subsidies on the first place, because he could not implement the SP project only with his own financial resources and the nowadays and new programming period will be focused on building SP´s, Technological centres, scientific labs ect. It is clear, that all decision makers attention will be given to building and financing of new SP, which will bring increase of circulation of industry information (he needs to find the specialization of the SP) and of course increase of operation costs. All the rest of variables will decrease. At this situation the decision maker will have to decide soon again how to lower the operation costs and increase all the rest of variables accept II.

5.2.10 Slow model based partially on second derivative

See Fig. 1	X	Y	
24	SQP	HBC	
23	HBC	QRD	
23	QE	OEC	
23	QRI	QE	
22	PI	CSC	
-	RDO	LU	(68)
+	PI	CS	
+	SQP	RDO	
+	HBC	CS	
+	QRD	CS	
+	HBC	QRI	
-	SQP	OEC	

The first five relations of the model (68) is based on the second derivatives, see Fig. 6. The first relation is represented in the model (27) just by qualitative proportionality. However the shape 24, see Fig. 6 indicates, that the second qualitative derivative DD(HBC)/DD(SQP) is positive. This additional qualitative information item makes the model (68) much more accurate. The team of experts was not able to make the last 7 relations of the model (68) more precise.

The corresponding slow scenarios are:

	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	PI	
1	+++	+-+	+-+	+-+	+-+	+--	+++	+--	+-+	+-+	+-+	
2	+++	+-+	+-+	+-+	+-0	+--	+++	+--	+-+	+-+	+-+	
3	+++	+-+	+-+	+-+	+--	+--	+++	+--	+-+	+-+	+-+	
4	+++	+--	+--	+--	+--	+--	+++	+--	+--	+--	+--	
5	++0	+-+	+-+	+-+	+-+	+-0	++0	+-0	+-+	+-+	+-+	(69)
6	++-	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+	+-+	
7	+0+	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0-	
8	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	
9	+0-	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0+	
10	+-+	+++	+++	+++	+++	++-	+-+	++-	+++	+++	+++	
11	+-+	+++	+++	+++	++0	++-	+-+	++-	+++	+++	+++	
12	+-+	+++	+++	+++	++-	++-	+-+	++-	+++	+++	+++	
13	+-+	++-	++-	++-	++-	++-	+-+	++-	++-	++-	++-	
14	+-0	+++	+++	+++	+++	++0	+-0	++0	+++	+++	+++	
15	+--	+++	+++	+++	+++	+++	+--	+++	+++	+++	+++	

The scenario No. 8 is the steady state scenario and it corresponds to the 2^{nd} scenario (37) of the model (31) based on the first derivatives only. The scenarios Nos. 1 – 15 are more accurate qualitative descriptions of the first set of scenarios (37), based on evaluated second derivative.

If we look closer to set (69) based on second derivatives we find out, that there is a difference between the results (37, 69). The reason is, that the model (68) includes more precise information, then model (31), where information is vague.

The complete graph of transitions among the set of scenarios (69) is represented by the Fig. 14. The Tab. 7 of the one dimensional transition is used.

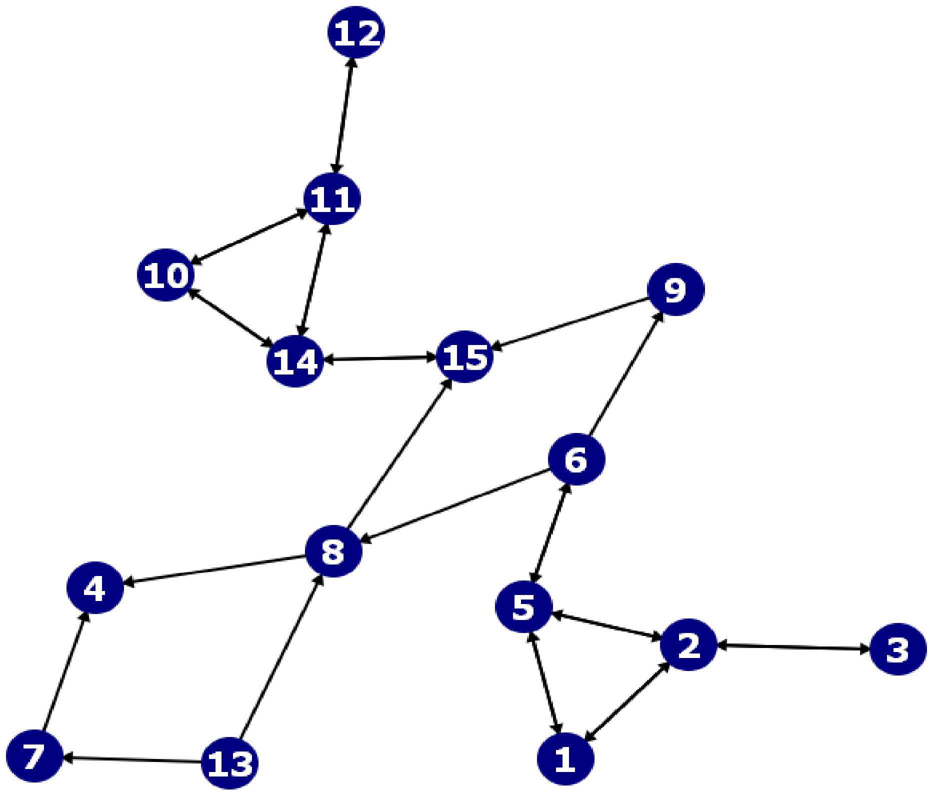

Fig. 14 - Graph of transitions among the set of scenarios (69)

If SQP is the goal, which mast be maximized, then the set of scenarios can be divided into the following subsets, see the first column of the matrix (69):

SQP	Scenario No.	
+++	1, 2, 3, 4,	
++0	5	
++-	6	
+0+	7	
+00	8	(70)
+0-	9	
+-+	10, 11, 12, 13	
+-0	14	
+--	15	

The best SQP behaviour is described by (+ + +) as it means, that SQP is increasing and the increase is higher and higher. The worst scenario is described by the triplet (+ - -), see the scenario No. 15 (69, Fig 14).

The optimal SQP triplet (+++) have the first four scenarios of the model (68), see result of set of scenarios (69). The following list of possible transitions from and to the set of scenarios with SQP (+++) has 6 elements.

No.	From	To	
1	1	2	
2	1	5	
3	2	1	
4	2	3	(71)
5	2	5	
6	3	2	

If a SP is described by the scenario 15, then there is escape road from the worst scenario, see Fig. 14. On the other hand if the SP behaviour is represented by a scenario from the set of scenarios (1, 2, 3, 4), then managerialand/or governmental bad decision can transfer the SP out of the best set of scenarios. It can also bring the SP back to the worst possible scenario No. 15. It means, that the favourable triplet (+ + +), see (69, 70), doesn't have to be valid for ever irrespective of any mistakes done by managements or governments.

Interpretation of the best SQP scenario No. 1 (69) could be:

Maximization of supply of qualified outside personnel will bring increase of the outlook of regional development. It will also cause gradual increase of human brain cultivation organizations, quality of R&D engineers, quality of research institutions, quality of enterprises, gradual increase in competition status of the region, completion of supply chain and gradual increase in prospect of industries. On the other hand maximization of SQP will bring decrease of occasion for enterprises cooperating and living utilities. This decrease of OEC could be still caused by the change in regional development outlook (increase). It is possible, that companies will react slower (with time delay) for change of regional prospects and new coming opportunities. Other reason could be the fact, that in SP will work new qualified outside personnel, so there will not be that urgent need to look for further cooperation. The increase of RDO will bring investments and people in to the region, which will cause shortage of suitable living utilities (flats, kindergartens, schools, health care act.)

Compromise decision could be scenario No. 10 (69):

Though maximization of supply of qualified outside personnel was a goal it did not bring large global positive effects for the region although the situation has considerably improved. If the decision maker makes a compromise and gradually increase the SQP, than the global positive effects for the region will be much higher.

Let us have a look at the situation of scenario No. 10 (69) in more detail.

If the SQP gradually increase, then human brain cultivation organizations will increase, the quality of R&D engineers will increase, the quality of research institutions will increase, the quality of enterprises will increase together with competition status of the region, completion of supply chain and prospect of industries will increase as well and the increase will be higher and higher. The cooperation between companies will be almost at its maximum, the living utilities will be sufficient and the regional development outlook will gradually increase. This path would bring more positive effects to the region, then scenario No. 1 (69).

Let´s do the test, what happens with result of model (68), if PI is the goal, which must be maximised. Model (68) and its links remain unchanged.

The corresponding slow scenarios are:

	PI	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	
1	+++	+-+	+++	+++	+++	+++	++-	+-+	++-	+++	+++	
2	+++	+-+	+++	+++	+++	++0	++-	+-+	++-	+++	+++	
3	+++	+-+	+++	+++	+++	++-	++-	+-+	++-	+++	+++	
4	+++	+-0	+++	+++	+++	+++	++0	+-0	++0	+++	+++	
5	+++	+--	+++	+++	+++	+++	+++	+--	+++	+++	+++	
6	++-	+-+	++-	++-	++-	++-	++-	+-+	++-	++-	++-	
7	+0+	+0-	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	
8	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	(72)
9	+0-	+0+	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	

10	+-+	+++	+-+	+-+	+-+	+-+	+--	+++	+--	+-+	+-+
11	+-+	+++	+-+	+-+	+-+	+-0	+--	+++	+--	+-+	+-+
12	+-+	+++	+-+	+-+	+-+	+--	+--	+++	+--	+-+	+-+
13	+-+	++0	+-+	+-+	+-+	+-+	+-0	++0	+-0	+-+	+-+
14	+-+	++-	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+
15	+--	+++	+--	+--	+--	+--	+--	+++	+--	+--	+--

The complete graph of transitions among the set of scenarios (72) is represented by the Fig. 15. The Tab. 7 of the one dimensional transition is used.

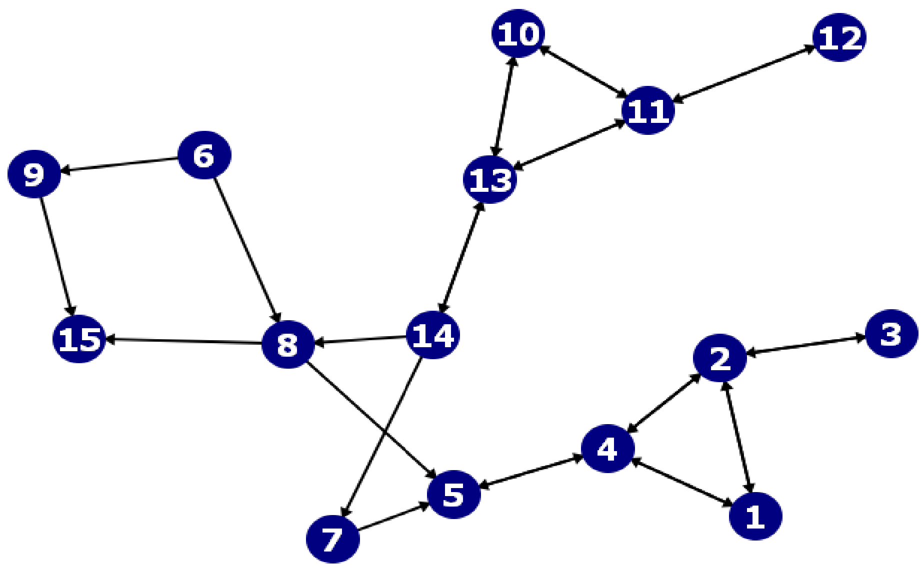

Fig. 15 - Graph of transitions among the set of scenarios (72)

If PI is the goal, which mast be maximized, then the set of scenarios can be divided into the following subsets, see the first column of the matrix (72):

PI	Scenario No.	
+++	1, 2, 3, 4, 5	
++-	6	
+0+	7	
+00	8	(73)
+0-	9	
+-+	10, 11, 12, 13, 14	
+--	15	

The best PI behaviour is described by (+ + +) as it means, that PI is increasing and the increase is higher and higher. The worst scenario is described by the triplet (+ - -), see the scenario No. 15 (72, Fig. 15).

The optimal PI triplet (+++) have five scenarios of the model (68), see result of set of scenarios (72). The following list of possible transitions from and to the set of scenarios with PI (+++) has 10 elements.

No.	From	To	
1	1	2	
2	1	4	
3	2	1	
4	2	3	
5	2	4	
6	3	2	(74)
7	4	1	
8	4	2	
9	4	5	
10	5	4	

If a SP is described by the scenario 15, then there is no way out of this bad situation, see Fig. 15. On the other hand if the SP behaviour is represented by a scenario 1, 2, 3, 4, 5, then a managerial or governmental decision can just transfer SP within this set. It means, that the favourable triplet (+ + +), see (73), will be valid for ever irrespective of any mistakes done by managements or governments.

Interpretation of the best PI scenario No. 1 (72) could be:

If there is an increase of prospects of industries, then there will be an increase in human brain cultivation organizations, increase in quality of R&D ingineers, increase in quality of research institutions, increase in quality of enterprises, increase in competition status and completion of supply chain, there will be lot of opportunities for cooperation between companies and sufficient living utilities. The supply of qualified outside personnel will gradually increasing together with regional development outlook.

However, the realistic transitional graphs are much more complex and more difficult to interpret. If the model (68) is slightly modified, then the number of transitions is relatively high. Just three model's (68) modifications are done:

1 if D(QRD) = (+) then 24 SQP HBC QRD
4 If D(PI) = (+) then 23 QRI QE PI (75)
10 if D(RDO) = (+) then M+_ QRD CS RDO

The macroinstructions Nos. 1, 4 a 10 are conditional. If the first derivatives D of QRD, PI and RDO are positive, then the corresponding macroinstructions (75) replace the original ones. Simple common sense reasoning indicates, that the number of scenarios for the modified model (68, 75) will be higher. The reason is, that the macroinstructions (75) are restrictive just for a specific values of three variables and not always.

The modified model (68, 75) has 72 scenarios and 266 transitions among them.

The modified model follow:

	PI	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC
1	+++	+++	+++	+++	+++	+-+	+--	+++	+--	+++	+++
2	+++	+-+	+++	+++	+++	+++	++-	+-+	++-	+++	+++
3	+++	+-+	+++	+++	+++	++0	++-	+-+	++-	+++	+++
4	+++	+-+	+++	+++	+++	++-	++-	+-+	++-	+++	+++
5	+++	+-0	+++	+++	+++	+++	++0	+-0	++0	+++	+++
6	+++	+--	+++	+++	+++	+++	+++	+--	+++	+++	+++
7	++-	+-+	++-	++-	++-	++-	++-	+-+	++-	++-	++-
8	+0+	+++	+0+	+0+	+0+	+-+	+--	+++	+--	+0+	+0+
9	+0+	+++	+0+	+0+	+0+	+-0	+--	+++	+--	+0+	+0+
10	+0+	+++	+0+	+0+	+0+	+--	+--	+++	+--	+0+	+0+
11	+0+	++0	+0+	+0+	+0+	+-+	+-0	++0	+-0	+0+	+0+
12	+0+	++-	+0+	+0+	+0+	+-+	+-+	++-	+-+	+0+	+0+
13	+0+	+0+	+0+	+0+	+0+	+0-	+0-	+0+	+0-	+0+	+0+
14	+0+	+00	+0+	+0+	+0+	+00	+00	+00	+00	+0+	+0+
15	+0+	+0-	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+
16	+0+	+-+	+0+	+0+	+0+	+++	++-	+-+	++-	+0+	+0+

17	+0+	+-+	+0+	+0+	+0+	++0	++-	+-+	++-	+0+	+0+	
18	+0+	+-+	+0+	+0+	+0+	++-	++-	+-+	++-	+0+	+0+	
19	+0+	+-0	+0+	+0+	+0+	+++	++0	+-0	++0	+0+	+0+	
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21	+00	+++	+00	+00	+00	+-+	+--	+++	+--	+00	+00	
22	+00	+++	+00	+00	+00	+-0	+--	+++	+--	+00	+00	
23	+00	+++	+00	+00	+00	+--	+--	+++	+--	+00	+00	
24	+00	++0	+00	+00	+00	+-+	+-0	++0	+-0	+00	+00	
25	+00	++-	+00	+00	+00	+-+	+-+	++-	+-+	+00	+00	
26	+00	+0+	+00	+00	+00	+0-	+0-	+0+	+0-	+00	+00	
27	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	
28	+00	+0-	+00	+00	+00	+0+	+0+	+0-	+0+	+00	+00	
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30	+00	+-+	+00	+00	+00	++0	++-	+-+	++-	+00	+00	
31	+00	+-+	+00	+00	+00	++-	++-	+-+	++-	+00	+00	
32	+00	+-0	+00	+00	+00	+++	++0	+-0	++0	+00	+00	
33	+00	+--	+00	+00	+00	+++	+++	+--	+++	+00	+00	
34	+0-	+++	+0-	+0-	+0-	+-+	+--	+++	+--	+0-	+0-	
35	+0-	+++	+0-	+0-	+0-	+-0	+--	+++	+--	+0-	+0-	(76)
36	+0-	+++	+0-	+0-	+0-	+--	+--	+++	+--	+0-	+0-	
37	+0-	++0	+0-	+0-	+0-	+-+	+-0	++0	+-0	+0-	+0-	
38	+0-	++-	+0-	+0-	+0-	+-+	+-+	++-	+-+	+0-	+0-	
39	+0-	+0+	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	
40	+0-	+00	+0-	+0-	+0-	+00	+00	+00	+00	+0-	+0-	
41	+0-	+0-	+0-	+0-	+0-	+0+	+0+	+0-	+0+	+0-	+0-	
42	+0-	+-+	+0-	+0-	+0-	+++	++-	+-+	++-	+0-	+0-	
43	+0-	+-+	+0-	+0-	+0-	++0	++-	+-+	++-	+0-	+0-	
44	+0-	+-+	+0-	+0-	+0-	++-	++-	+-+	++-	+0-	+0-	
45	+0-	+-0	+0-	+0-	+0-	+++	++0	+-0	++0	+0-	+0-	
46	+0-	+--	+0-	+0-	+0-	+++	+++	+--	+++	+0-	+0-	
47	+-+	+++	+-+	+-+	+-+	+-+	+--	+++	+--	+-+	+-+	
48	+-+	+++	+-+	+-+	+-+	+-0	+--	+++	+--	+-+	+-+	
49	+-+	+++	+-+	+-+	+-+	+--	+--	+++	+--	+-+	+-+	
50	+-+	++0	+-+	+-+	+-+	+-+	+-0	++0	+-0	+-+	+-+	

51	+-+	++-	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+
52	+-+	+0+	+-+	+-+	+-+	+0-	+0-	+0+	+0-	+-+	+-+
53	+-+	+00	+-+	+-+	+-+	+00	+00	+00	+00	+-+	+-+
54	+-+	+0-	+-+	+-+	+-+	+0+	+0+	+0-	+0+	+-+	+-+
55	+-+	+-+	+-+	+-+	+-+	+++	++-	+-+	++-	+-+	+-+
56	+-+	+-+	+-+	+-+	+-+	++0	++-	+-+	++-	+-+	+-+
57	+-+	+-+	+-+	+-+	+-+	++-	++-	+-+	++-	+-+	+-+
58	+-+	+-0	+-+	+-+	+-+	+++	++0	+-0	++0	+-+	+-+
59	+-+	+--	+-+	+-+	+-+	+++	+++	+--	+++	+-+	+-+
60	+--	+++	+--	+--	+--	+-+	+--	+++	+--	+--	+--
61	+--	+++	+--	+--	+--	+-0	+--	+++	+--	+--	+--
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65	+--	+0+	+--	+--	+--	+0-	+0-	+0+	+0-	+--	+--
66	+--	+00	+--	+--	+--	+00	+00	+00	+00	+--	+--
67	+--	+0-	+--	+--	+--	+0+	+0+	+0-	+0+	+--	+--
68	+--	+-+	+--	+--	+--	+++	++-	+-+	++-	+--	+--
69	+--	+-+	+--	+--	+--	++0	++-	+-+	++-	+--	+--
70	+--	+-+	+--	+--	+--	++-	++-	+-+	++-	+--	+--
71	+--	+-0	+--	+--	+--	+++	++0	+-0	++0	+--	+--
72	+--	+--	+--	+--	+--	+++	+++	+--	+++	+--	+--

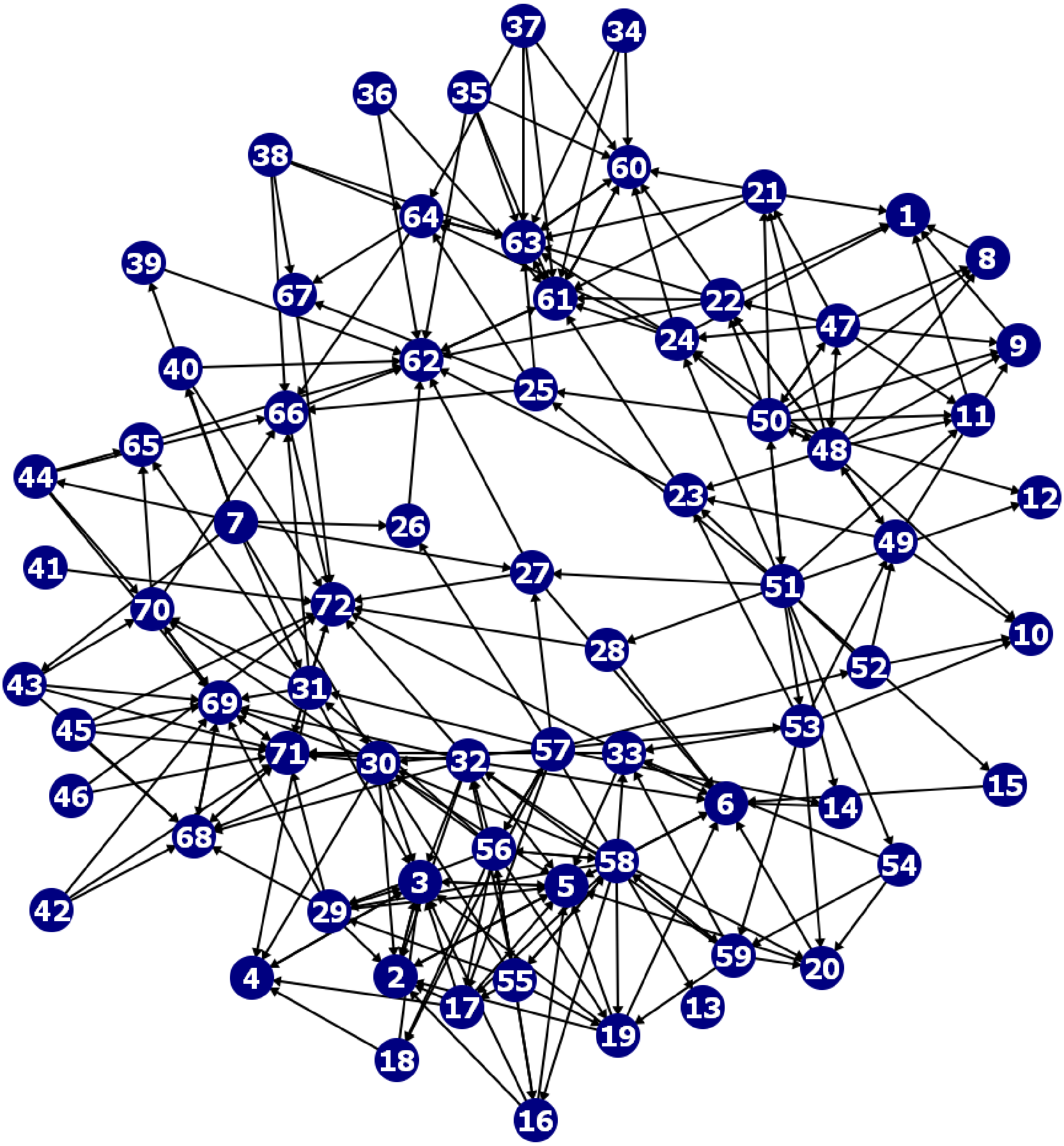

Fig. 16 - Graph of transitions among the set of scenarios (76)

It means, that the graph is significantly more complex if compared with the transition graph Fig. 15. It is difficult to identify all possible oriented loops in such complex graph.

The optimal PI triplet (+ + +) have 6 scenarios of the modified model (68, 75), see (76). The following list of possible transitions from and to the set of scenarios with the PI (+ + +) has 10 elements.

No.	From	To	
1	2	3	
2	2	5	
3	3	2	
4	3	4	
5	3	5	(77)
6	4	3	
7	5	2	
8	5	3	
9	5	6	
10	6	5	

The interpretation of the set of scenarios (76) depends on the nature of the variables (24). Different variables are controlled by government (GOV), management (MAN) and local authorities (LAU). Some variables are not directly controlled as they are goals (GOA):

	Controlled by		
Supply of qualified outside personnel	SQP	GOV	
Human brain cultivation organizations	HBC	GOV	
Quality of R&D engineers	QRD	MAN	
Quality of research institution	QRI	MAN	
Quality of enterprises	QE	MAN	
Occasion for enterprises cooperating	OEC	MAN	(78)
Regional development outlook	RDO	GOV	
Living utilities	LU	LOA	
Competition status	CS	MAN	
Completion of supply chain	CSC	MAN	
Prospects of industries	PI	GOA	

There is just one goal to be achieved/maximized, namely the prospects of industries PI. The first and the second scenario have their pros and cons. However our subject evaluation prefers the second scenario as we strongly believe, that increase of QE is more important, then the unplease decrease of OEC. Scenario No. 1. It means, that the second scenario (76) is desirable. However to achieve this scenario a cooperation of the management, government and local authorities is inevitable.

The set of the best PI scenarios is the set of the first 6 scenarios (76):

	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	
1	+++	+++	+++	+++	+-+	+--	+++	+--	+++	+++	
2	+-+	+++	+++	+++	+++	++-	+-+	++-	+++	+++	
3	+-+	+++	+++	+++	++0	++-	+-+	++-	+++	+++	(79)
4	+-+	+++	+++	+++	++-	++-	+-+	++-	+++	+++	
5	+-0	+++	+++	+++	+++	++0	+-0	++0	+++	+++	
6	+--	+++	+++	+++	+++	+++	+--	+++	+++	+++	

This set (79) can be characterized as follows:

SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	(80)
↑↓	↑	↑	↑	↑↓	↑↓	↑↓	↑↓	↑	↑	
GOV	GOV	MAN	MAN	MAN	MAN	GOV	LOA	MAN	MAN	

where arrows indicate increase or decrease of the corresponding variables in the set of scenarios (79).

If Regional development outlook RDO is interpreted as a goal GOA and not controlled by a government, then two objective functions must be maximized. There is just one scenario, which maximizes both objective functions, see No. 1 in (79). There is just one scenario, which has the worst possible triplet (+ - -), see (76), as the descriptor for both objective functions PI and RDO, namely the scenario No. 72.

PI	RDO	(81)
IN	IN	

It means, that both goals can be achieved at the same time.

Interpretation of the best result of conditional model (68, 75) could be:

If the decision maker wants to maximize prospect of industries together with regional development outlook, then there must be an increase in supply of qualified outside personnel, increase in human brain cultivation organizations, increase in quality of R&D engineers, increase in quality of research institucions, increase in competition status of the region and increase in completion of supply chain. The quality of enterprises will gradually increase, while the occasion for enterprises cooperating will still decrease together with suitable living utilities. The decrease in occasion for enterprises cooperating could be caused by only gradual improvement in quality of companies and lack of information.

Compromise solution of conditional model (68, 75) could be scenario No. 2 (76):

If the decision maker chooses compromise solution scenario No. 2 (76), then the increase in prospect of industries will bring an increase in number of human brain cultivation organizations, increase in quality of R&D engineers, increase in quality of research institucions, increase in quality of enterprises, increase in completion of supply chain and increase in competition status of the region. In the mean while there will be almost maximum possible cooperation between companies and the living utilities will also be at very good level. There will be gradual increase in supply of qualified outside personnel together with gradual increase in regional development outlook. One goal will be achieved immediately (increasing PI) and the second one will take longer time period as the increase of regional development outlook will be just gradually starting.

As we can see, the key factor of increase of regional development outlook are innovations and supply of qualified outside personnel. The competition status of the region is increasing, if there is an increase in prospect of industries.

The above part of the case study presents the development of a qualitative model in practice. The qualitative model in practice is developed and will be developed in many steps. It all depends on the amount of information, that gets the decision maker during his decision making process and will evaluate them as important and relevant for his decision about investment into SP.

Let´s have a look, what happens, if more complete (accurate) fast and slow model is defined as a result of discussions of group of experts.

The reason of those changes is, that team of experts adjusted fast and slow model with more precise information, which lead to more precise results.

Following fast model (82) partially incorporates additional information items based on second derivatives:

5.2.11 The fast model and its results:

See Fig. 1	X	Y	
23	IR	NJC	
21	CIA	CII	
25	SI	II	
23	BES	BP	
+	BES	RE	(82)
+	RE	NJC	
+	BES	IR	
-	RE	OC	
+	CIA	IR	
+	CIA	RE	
+	**II**	**NJC**	
-	**BES**	**OC**	
+	**CII**	**BES**	
+	**CII**	**BP**	

Relations between variables of different subsets (26) were completed by team of experts for other relevant relations between different variables. This adjustment of the model (82) came out of discussion.

There are 7 fast scenarios:

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	+++	+++	+++	+++	+--	+++	+++	+++	+++	+--	
2	++-	++-	++-	++-	+-+	++-	++-	++-	++-	+-+	
3	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0+	+0-	
4	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	(83)
5	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0-	+0+	
6	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+	+-+	++-	
7	+--	+--	+--	+--	+++	+--	+--	+--	+--	+++	

It follows, that in model (47, 51) some important relations between variables were overlooked and the computer generated larger number of scenarios. After adjustment of the model (51) the number of scenarios dropped from 15 (52) to 7 (83).

If we look closer to the set of scenarios (52, 83) we find out, that the first and last scenarios for the monitored variables CIA, CII, IR are the same, but the whole first and last scenarios (52, 83) are actually different.

The difference between the two first and last scenarios (52, 83) is, that in first fast scenario (52) II and OC are decreasing and the rest of variables is increasing. In the first fast scenario (83) SI and OC are decreasing and the rest of variables is increasing. In the last fast scenarios (52, 83) triplets develop oppositely, then in the first fast scenarios (52, 83) with the same differences.

The decision maker must look at the reality in the region, where he wants to implement his project and find the fastest way how to achieve his goals see Fig. 17 (83).

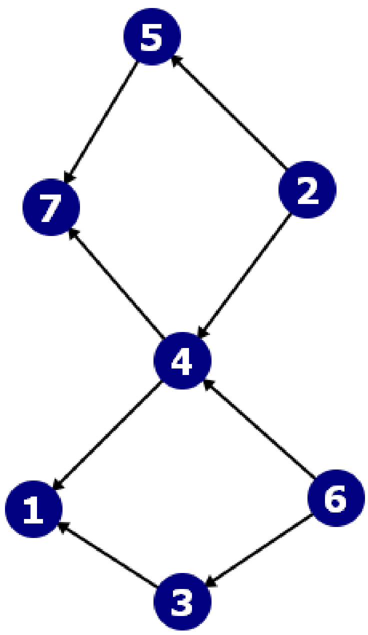

Fig. 17 - Graph of transitions among the set of scenarios (83)

List of possible transitions to the set of scenarios with CIA (+++) has two elements see Fig. 17. There is only one scenario with the best possible CIA, see (Fig. 17, 83) and one worst possible scenario No. 7 see (Fig. 17, 83).

No.	From	To	Number of changed variables
1.	2	4	10
2.	2	5	10
3.	3	1	10
4.	4	1	10
5.	4	7	10
6.	5	7	10
7.	6	3	10
8.	6	4	10

(84)

Let´s do the test, what happens with result of model (82), if II is the goal, which mast be maximized. Model (82) and its links remain unchanged.

There are 7 fast scenarios:

	II	CIA	CII	IR	NJC	SI	BES	RE	BP	OC
1	+++	+++	+++	+++	+++	+--	+++	+++	+++	+--
2	++-	++-	++-	++-	++-	+-+	++-	++-	++-	+-+
3	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-
4	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00
5	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+
6	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-
7	+--	+--	+--	+--	+--	+++	+--	+--	+--	+++

(85)

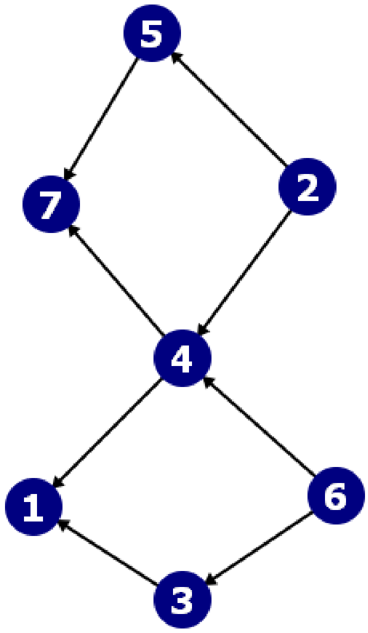

Fig. 18 - Graph of transitions among the set of scenarios (85)

The test results showed consistency with the matrix (83)

List of possible transitions to the set of scenarios with II (+++) has two elements see Fig. 18. There is only one scenario with the best possible II, see (Fig. 18, 85) and one worst possible scenario No. 7 see (Fig. 18, 85).

No.	From	To	Number of changed variables	
1.	2	4	10	
2.	2	5	10	
3.	3	1	10	
4.	4	1	10	(86)
5.	4	7	10	
6.	5	7	10	
7.	6	3	10	
8.	6	4	10	

The interpretation of situation (52) could be:

If there is an increase of cooperation between industries and academics, then the circulation of industry information is increasing, incubator resources are increasing, new jobs creation is increasing, scale of industries is increasing, benefit of economies of scale is increasing and the bargaining power and reputation are increasing as well and the increase is higher and higher. This situation leads to decrease in need for incentives for investment and in operation costs (always wanted).

The interpretation of situation (83, 85) could be:

If there is an increase of cooperation between industries and academics, then the circulation of industry information is increasing, incubator resources are increasing, new jobs creation is increasing, investment incentives are increasing, benefit of economies of scale is increasing and the bargaining power and reputation are increasing as well. This increase leads to decrease in scale of industries (specialization) and decrease in operation costs. This could be a situation of existing prosperous SP park, which draws subsidies for specific research in certain field.

If we compare those two result situations, both could be possible. SP in situation (52) scenario No. 1 doesn't have the goal to maximize increase of investment incentives, because its operation costs are already decreasing and incubator resources are increasing. The goals are achieved. SP in situation (83) corresponds to the possible trend in the coming years, which also implies the establishment of medium and smaller SP parks/Technology centres/science labs etc. (e.g. specialization for certain field). It means, that the scale of industry will decline together with decrease of operational costs. If we look at it economically all the goals will be achieved.

Let´s look at the completed fast model in more detail:

Different variables within the fast model are controlled by managements (MAN) and government GOV. Some variables are not directly controlled as they are goals (GOA):

	Controlled by		
New jobs creation	NJC	MAN	
Incubator resources	IR	MAN	
Cooperation between industries and academics	CIA	GOA	
Circulation of industry information	CII	MAN	
Scale of industries	SI	MAN	
Incentives for investment	II	GOV	(87)
Operation costs	OC	MAN	
Benefit of economies of scale	BES	MAN	
Bargaining power	BP	MAN	
Reputation	RE	MAN	

There is just one goal to be achieved/maximized namely increase the cooperation between industries and academics CIA. It means, that the first scenario (83) is desirable. However to achieve this scenario a cooperation of the managements and government is inevitable.

CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
IN	IN	IN	IN	DE	IN	IN	IN	IN	DE	(88)
MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	

where DE is decrease, IN is increase.

If Incentives for investment II is interpreted as a goal GOA and not controlled by a government, then two objective functions must be maximised.

CIA	II	(89)
IN	IN	

It means, that both goals can be achieved at the same time see (83) scenario No. 1 and (88).

However, the realistic transitional graphs are much more complex and more difficult to interpret. If the model (82) is slightly modified, then the number of transitions is relatively high. Just four model's (82) modifications are done:

1 if D (IR) = (+) then 23 IR NJC IR
2 if D (CIA) = (+) then 21 CIA CII CIA (90)
3 if D (II) = (+) then 25 SI II II
9 if D (CII) = (+) then M+_CIA IR CII

The macro-instructions Nos. 1, 2, 3 a 9 are conditional. If the first derivatives D of IR, CIA, II and CII are positive, then the corresponding macroinstructions (90) replace the original ones. Simple common sense reasoning indicates, that the number of scenarios for the modified model (82) will be higher. The reason is, that the macroinstructions (90) are restrictive just for a specific values of four variables and not always.

The modified model (82, 90) has 48 scenarios and 144 transitions among them.

The modified model scenarios follow:

	II	CIA	CII	IR	NJC	SI	BES	RE	BP	OC
1	+++	+++	+++	+++	+++	+++	+++	+++	+++	+--
2	+++	+++	+++	+++	+++	+--	+++	+++	+++	+--
3	++-	++-	++-	++-	++-	+-+	++-	++-	++-	+-+
4	+0+	+0+	+0+	+0+	+0+	+++	+0+	+0+	+0+	+0-
5	+0+	+0+	+0+	+0+	+0+	++0	+0+	+0+	+0+	+0-
6	+0+	+0+	+0+	+0+	+0+	++-	+0+	+0+	+0+	+0-
7	+0+	+0+	+0+	+0+	+0+	+0+	+0+	+0+	+0+	+0-
8	+0+	+0+	+0+	+0+	+0+	+00	+0+	+0+	+0+	+0-
9	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-
10	+0+	+0+	+0+	+0+	+0+	+-+	+0+	+0+	+0+	+0-
11	+0+	+0+	+0+	+0+	+0+	+-0	+0+	+0+	+0+	+0-
12	+0+	+0+	+0+	+0+	+0+	+--	+0+	+0+	+0+	+0-
13	+00	+00	+00	+00	+00	+++	+00	+00	+00	+00
14	+00	+00	+00	+00	+00	++0	+00	+00	+00	+00
15	+00	+00	+00	+00	+00	++-	+00	+00	+00	+00
16	+00	+00	+00	+00	+00	+0+	+00	+00	+00	+00
17	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00
18	+00	+00	+00	+00	+00	+0-	+00	+00	+00	+00
19	+00	+00	+00	+00	+00	+-+	+00	+00	+00	+00

20	+00	+00	+00	+00	+00	+-0	+00	+00	+00	+00	
21	+00	+00	+00	+00	+00	+--	+00	+00	+00	+00	
22	+0-	+0-	+0-	+0-	+0-	+++	+0-	+0-	+0-	+0+	
23	+0-	+0-	+0-	+0-	+0-	++0	+0-	+0-	+0-	+0+	(91)
24	+0-	+0-	+0-	+0-	+0-	++-	+0-	+0-	+0-	+0+	
25	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
26	+0-	+0-	+0-	+0-	+0-	+00	+0-	+0-	+0-	+0+	
27	+0-	+0-	+0-	+0-	+0-	+0-	+0-	+0-	+0-	+0+	
28	+0-	+0-	+0-	+0-	+0-	+-+	+0-	+0-	+0-	+0+	
29	+0-	+0-	+0-	+0-	+0-	+-0	+0-	+0-	+0-	+0+	
30	+0-	+0-	+0-	+0-	+0-	+--	+0-	+0-	+0-	+0+	
31	+-+	+-+	+-+	+-+	+-+	+++	+-+	+-+	+-+	++-	
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35	+-+	+-+	+-+	+-+	+-+	+00	+-+	+-+	+-+	++-	
36	+-+	+-+	+-+	+-+	+-+	+0-	+-+	+-+	+-+	++-	
37	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+-+	++-	
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42	+--	+--	+--	+--	+--	++-	+--	+--	+--	+++	
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45	+--	+--	+--	+--	+--	+0-	+--	+--	+--	+++	
46	+--	+--	+--	+--	+--	+-+	+--	+--	+--	+++	
47	+--	+--	+--	+--	+--	+-0	+--	+--	+--	+++	
48	+--	+--	+--	+--	+--	+--	+--	+--	+--	+++	

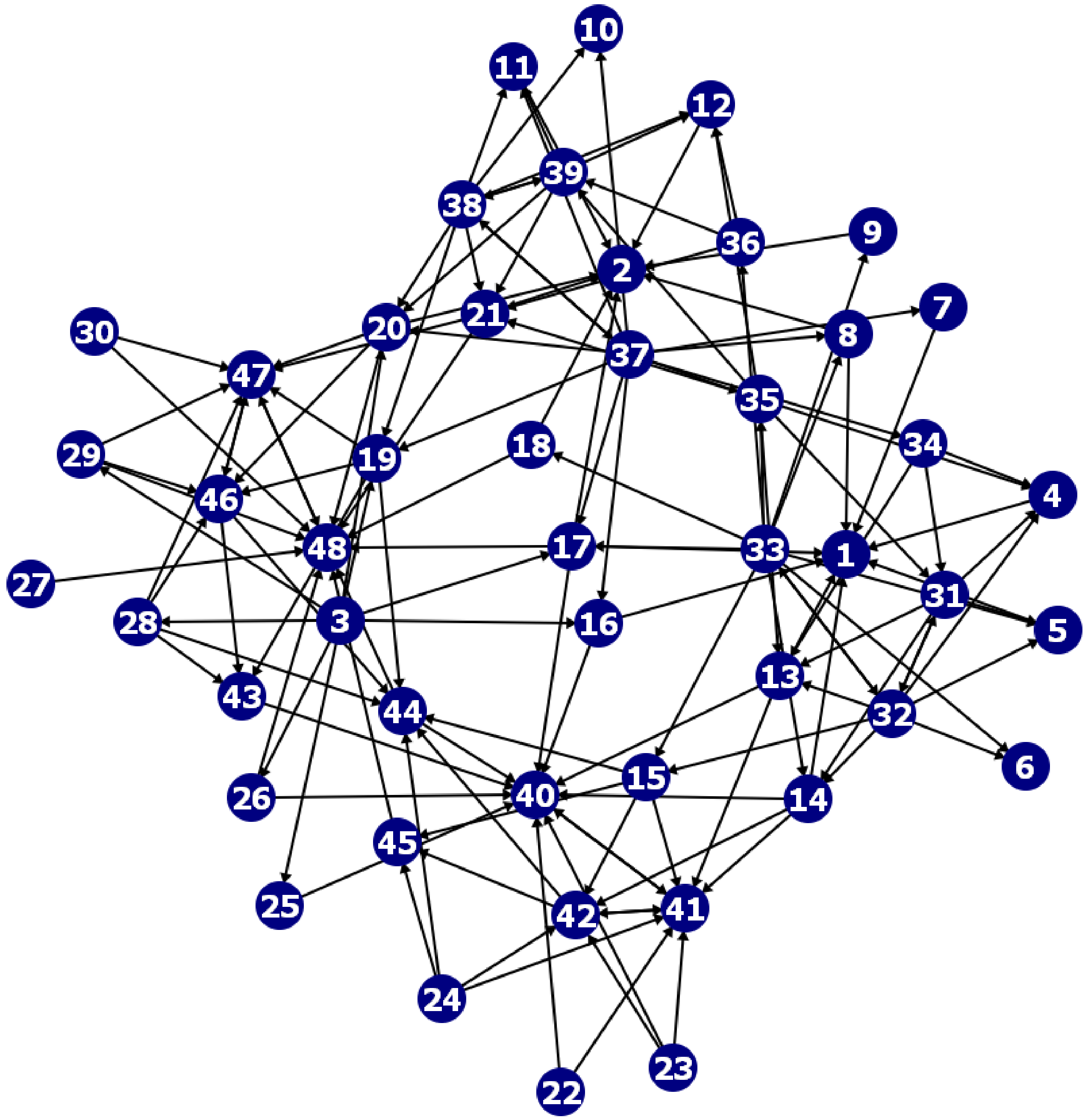

Fig. 19 Graph of transitions among the set of scenarios (91)

The optimal II triplet (+ + +) have two scenarios of the modified model (82, 90), see set of scenarios (91). The following list of possible transitions to the set of scenarios with the II (+ + +) has five elements.

No.	From	To	Number of changed variables
1.	3	16	10
2.	3	17	10
3.	3	19	9
4.	3	20	10
5.	3	25	10
6.	3	26	10
7.	3	28	9
8.	3	29	10
9.	4	1	9
10.	5	1	10
11.	7	1	10
12.	8	1	10
13.	8	2	10

(92)

It means, that the graph is significantly more complex if compared with the transition graph on Fig. 18. It is difficult to identify all possible oriented loops in such complex graph.

The interpretation of the set of scenarios (91) depends on the nature of the variables (25). Different variables are controlled by managements (MAN) and government GOV. Some variables are not directly controlled as they are goals (GOA):

		Controlled by
New jobs creation	NJC	MAN
Incubator resources	IR	MAN
Cooperation between industries and academics	CIA	MAN
Circulation of industry information	CII	MAN
Scale of industries	SI	MAN
Incentives for investment	II	GOA
Operation costs	OC	MAN
Benefit of economies of scale	BES	MAN
Bargaining power	BP	MAN
Reputation	RE	MAN

(93)

There is just one goal to be achieved/maximized namely the incentives for investment II and not controlled by a government. It means, that the first scenario (91) is desirable. However to achieve this scenario a cooperation of the managements is inevitable.

The set of the best II scenarios is the set of the first 2 scenarios (91):

	CIA	CII	IR	NJC	SI	BES	RE	BP	OC	(94)
1	+++	+++	+++	+++	+++	+++	+++	+++	+--	
2	+++	+++	+++	+++	+--	+++	+++	+++	+--	

The set of scenarios (94) can be characterised as follows:

CIA	CII	IR	NJC	SI	BES	RE	BP	OC	
$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$	(95)
MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	MAN	

where arrows indicate increase or decrease of the corresponding variables in the set of scenarios (94).

If incubator resources IR are interpreted as a goal GOA, then two objective functions must be maximised. There are two scenarios No. 1 and 2, which maximizes both objective functions, see (91, 94). There is nine worst possible triplet, where both functions are decreasing (+ - -), see 40-48 (91).

Interpretation of the best result of conditional model (82, 90) could be:

If the decision maker is willing to invest his free financial resources to implement SP project only under conditions, that the incubator resources will increase, the cooperation between industries and academics will increase, incentives for investment will increase and circulation of industry information will increase, then it is clear, that he will look for destination with increasing RDO and thus increasing CS, increasing PI, HBC, QRD, QRI, QE, OEC and CSC.

In that case, he can achieve his goal to draw maximum subsidies and in the mean while he can already achieve increasing cooperation between industries and academics, increasing circulation of industry information, increasing incubator resources, increase of new job creation, increase of scale of industries, increase in benefits of economies of scale and of course increase of bargaining power and reputation. Increase in benefits of economies of scale brings decrease of operation costs.

This study shows us, that this investor would choose for building up of SP destination, which the European Commission pointed in fifth Cohesion report as developed regions (Prague, Central Bohemia or South Moravia). It is interesting, that the European Commission plans for the new programming period 2014-2020 to allocate resources in these regions divided into a relatively large portion going into science and research at the expense of investment in infrastructure development.

The growth of Czech republic competitiveness, however, needs to increase the competitiveness of all regions and not only selected ones, even there will still be large difference between each of them.

Following slow model (96) partially incorporates additional information items based on second derivatives:

5.2.12 The slow model and its results:

See Fig. 1	X	Y	
24	SQP	HBC	
23	HBC	QRD	
23	QE	OEC	
23	QRI	QE	
22	PI	CSC	
-	RDO	LU	(96)
+	PI	CS	
+	HBC	CS	
+	QRD	CS	
+	HBC	QRI	
-	SQP	OEC	
+	QRI	QRD	
+	PI	OEC	
+	**PI**	**QE**	

+	**RDO**	**OEC**
-	**LU**	**QE**
+	**OEC**	**CSC**

Relations between variables of different subsets (26) were completed by team of experts for other relevant relations between variables which came out of discussion.

There are 7 slow scenarios:

	PI	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CS	CSC	
1	+++	+--	+++	+++	+++	+++	+++	+++	+--	+++	+++	
2	++-	+-+	++-	++-	++-	++-	++-	++-	+-+	++-	++-	
3	+0+	+0-	+0+	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	
4	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	(97)
5	+0-	+0+	+0-	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	
6	+-+	++-	+-+	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	
7	+--	+++	+--	+--	+--	+--	+--	+--	+++	+--	+--	

It follows, that in model (68) some important relations between variables were overlooked and the computer generated larger number of scenarios. After adjustment of the model, see (96) the number of scenarios dropped from 15 (72) to 7 (97).

If we look closer to the set of scenarios (72, 97) we find out, that the first and last scenario for the monitored variables SQP, PI, RDO has changed.

The difference between the two first and last slow scenarios (72, 97) is, that in first slow scenario (72) PI was increasing and SQP, RDO were gradually increasing. In the first slow scenario (97) PI and RDO are increasing, SQP is decreasing. In the last slow scenarios (72, 97) is also difference, in last slow scenario (72) SQP and RDO are increasing and the rest of variables is decreasing, while in last slow scenario (97) SQP and LU are increasing and the rest of variables is decreasing.

The interpretation of situation (72) could be:

If there is already an increase in prospect of industries, which means, that the number of human brain cultivation organizations is increasing, quality of R&D engineers is increasing, quality of research institutions is increasing, quality of enterprises is increasing, competition status of the region is increasing and the completion of supply chain is increasing, and this increase is higher and higher, than the occasion for enterprise cooperating is ritching its maximum, there are suitable living utilities. There is gradual increase in supply of qualified outside personnel and regional development outlook.

The interpretation of situation (97) could be:

If there is already an increase in prospect of industries, the number of human brain cultivation organizations is increasing, quality of R&D engineers and quality of research institutions is increasing, quality of enterprises is increasing together with occasion for enterprises cooperating, completion of supply chain is increasing and competition status of the region is increasing together with regional development outlook and this increase is higher and higher. In the meanwhile the living utilities are decreasing (because the increaseis faster, then the reaction of the local authority to build suitable LU) and there is decrease in supply of qualified outside personnel.

If we realize, that those are results of slow scenarios, where the evolution takes relatively long period of time, than we see, that both situations are possible to happen. The decision maker must come from the situation of the region,where he wants to implement his investment.

Let´s look at both results closer:

SP in situation (72) scenario No. 1, where is gradual increase of regional development outlook needs to get in to the region outside qualified personnel to keep and to run the development further and to support the occasions for enterprise cooperating and living utilities increase.

SP (97) is in different situation. The difference is, that the regional development outlook is increasing and the increase is higher and higher. In this situation it is not necessary to bring so big number of qualified outside personnel, the quality of R&D engineers, research and development institutions and human brain cultivation organizations are at quite good level and are still improving. The development and implementation of new investments is so fast, that the local authority doesn’t react fast enough on insufficient living utilities.

Anyway the decision maker must face the reality and find the fastest way how to achieve his goals see Fig. 15 and Fig. 20.

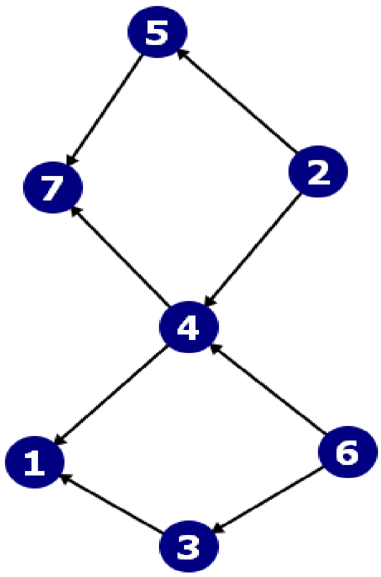

Fig. 20 - Graph of transitions among the set of scenarios (97)

Let us again slightly modify adjusted model (96). Just four model's (96) modifications are done:

1 if D(QRD) = (+) then 24 SQP HBC QRD
4 if D(PI) = (+) then 23 QRI QE PI
9 if D(RDO) = (+) then M+_ QRD CS RDO (98)
12 if D (CS) = (+) then M+_ QRI QRD CS

The macroinstructions Nos. 1, 4, 9 and 12 are conditional. If the first derivatives D of QRD, PI, RDO and CS are positive, then the corresponding macroinstructions (98) replace the original ones.

There are 7 slow scenarios:

	CS	PI	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CSC	
1	+++	+++	+--	+++	+++	+++	+++	+++	+++	+--	+++	
2	++-	++-	+-+	++-	++-	++-	++-	++-	++-	+-+	++-	
3	+0+	+0+	+0-	+0+	+0+	+0+	+0+	+0+	+0+	+0-	+0+	
4	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	(99)
5	+0-	+0-	+0+	+0-	+0-	+0-	+0-	+0-	+0-	+0+	+0-	
6	+-+	+-+	++-	+-+	+-+	+-+	+-+	+-+	+-+	++-	+-+	
7	+--	+--	+++	+--	+--	+--	+--	+--	+--	+++	+--	

The modified model (96, 98) has 7 scenarios and 8 transitions among them.

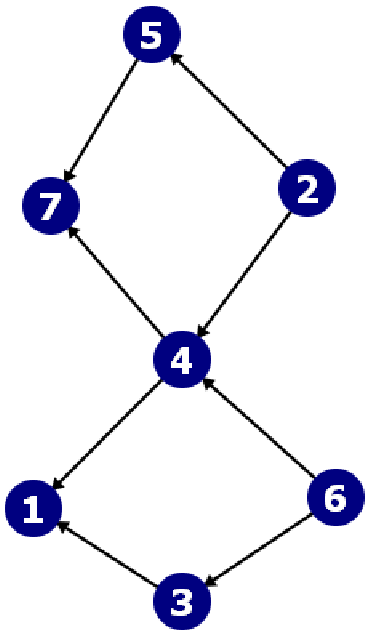

Fig. 21 - Graph of transitions among the set of scenarios (99)

The interpretation of the set of scenarios (99) depends on the nature of the variables (24). Different variables are controlled by government (GOV), management (MAN) and local authorities (LAU). Some variables are not directly controlled as they are goals (GOA):

		Controlled by	
Supply of qualified outside personnel	SQP	GOV	
Human brain cultivation organizations	HBC	GOV	
Quality of R&D engineers	QRD	MAN	
Quality of research institution	QRI	MAN	
Quality of enterprises	QE	MAN	
Occasion for enterprises cooperating	OEC	MAN	(100)
Regional development outlook	RDO	GOV	
Living utilities	LU	LAU	
Competition status	CS	GOA	
Completion of supply chain	CSC	MAN	
Prospects of industries	PI	GOV	

There is just one goal to be achieved/maximized namely the competition status CS. It means, that the first scenario (99) is desirable. However to achieve this scenario a cooperation of the management, government and local authorities is inevitable.

The set of the best CS scenario (99):

	PI	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CSC	(101)
1	+++	+--	+++	+++	+++	+++	+++	+++	+--	+++	

This scenario (101) can be characterized as follows:

PI	SQP	HBC	QRD	QRI	QE	OEC	RDO	LU	CSC	(102)
↑	↓	↑	↑	↑	↑	↑	↑	↓	↑	
GOV	GOV	GOV	MAN	MAN	MAN	MAN	GOV	LOA	MAN	

where arrows indicate increase or decrease of the corresponding variables in the scenario (101).

If Regional development outlook RDO is interpreted as a goal GOA and not controlled by a government, then two objective functions must be maximised. There is just one scenario, which maximizes both objective functions, see No. 1 in (99). There is just one scenario, which has the worst possible triplet (+ - -), see (99), as the descriptor for both objective functions CS and RDO, namely the scenario No. 7.

$$\frac{CS}{IN} \quad \frac{RDO}{IN} \qquad (103)$$

It means, that both goals can be achieved at the same time.

Interpretation of modified model (96, 98):

If the decision maker wants to increase the competitiveness of the region together with regional development outlook, which is closely related with investments in R&D and innovations, then there must be an increase in prospect of industries, increase in human brain cultivation organizations, quality of R&D engineers, quality of research institutions, increase in quality of enterprises and occasions for enterprises cooperating and increase in completion of supply chain. Supply of qualified outside personnel will decrease together with suitable living utilities.

f we look at both models (fast and slow), then we find out, that both models are complementary and may even influence each others.

If the decision maker is deciding to build SP, then he should consider all possible situations and obstacles, which could prevent his investment, or bring his SP project into fail. The decision maker must plan and prepare the ground for his project. Slow and fast variables must be monitored and the best solution must be find.

At present and in the future, there will be possibility to draw grants for science, research and constructions of major scientific and technological parks. This will be accompanied by a large number of changes. It is necessary to analyze the current situation in order to decide where and in what to invest the European money.

If we look at the results of slow and fast model closely, we find out:

If the goal is to draw maximum of subsidies, then the decision maker must prepare the ground for increasing cooperation between industries and academics, which increase the circulation of industry information, increase in incubator resources, increase in new job creation, increase in scale of industry which is connected to increase in benefits of economies of scale. This all will bring increase in bargaining power and reputation. In the meanwhile the operation costs will decrease. This is the ideal situation, which can be reached only if there is positive development of slow variables.

Let´s have a look at the slow scenarios:

To reach above positive situation in SP investment, there must be increasing regional development outlook, increasing competition status of the region, increasing prospect of industries, increasing human brain cultivation organizations, increasing quality of R&D engineers, increasing quality of research institutions, quality of companies and cooperation between them, increasing copletion of supply chain. At the same time, there will be decreasing supply of qualified outside personnel and decreasing living utilities.

5.3 Summary of granted options

First we must establish variables, that characterize best the fast variables of science park (SP) and slow variables characterizing the neighborhood (the region, where the SP is located). Then we must create a functional and real links between these variables. Since the variables are characterized by different time series, we woun´t mix fast and slow models.

Based on qualitative analysis of fast and slow models, we learn many interesting information about the SP and its surroundings, which are important for our future investment or other decisions relating to the SP and the region where SP occurs. If we were only interested in one particular model, we get the comparison to how he rates in comparison with other possible models (more detailed, less detailed models). A set of potential scenarios can be reduced using other links, that identify the SP environment and its surroundings in the model. Of course we must do it separatly for slow and fast models.

Furthermore, we get the possible scenarios and qualitative transitions between them, which may contribute to the successful achievement of a desired goal. They show us the way, how best to achieve our goals and how to avoid scenarios, where we do not want to achieve. We must realize, that although we have more potential candidates for the following scenario, but we know mainly remaining scenarios, that may occur. This information seems to be very important, because the model predicts what may or may not explicitly occur, if the decision-maker or other entity make a certain decision.

Then we got Qualitative Multi-Objective Optimization, that will help us to identify scenarios, where we would like to achieve, since they are the most optimal for us.

5.4 Contribution and utility of this research

The developed algorithms based on qualitative modelling and built up SP methodology of vague analysis facilitate optimization and decision making process about Science Parks in cases, where there are many possible alternative decisions.

The calculi must be made so flexible, that they can formalize and integrate vague and inconsistent knowledge with the minimum amount of knowledge loss. It is then much easier for the decision makers to choose from this well described set of alternative decisions. However the correctness of the results is influenced by the quality of researched informations. The set of scenarios must be provably complete i.e. there cannot be any other qualitative behaviours, that are not generated by the qualitative model. If important details are not taken into account in the qualitative model, then the results may not be precise or may be skewed. Therefore it is essential to input true and complete information and carefully create set of all relevant criteria for the particular decision.

5.4.1 Theoretical contribution of this research:

Programming algorithms based on qualitative modelling and built up SP methodology of vague analysis, that facilitates optimization of decision making process about science parks.

The theoretical contribution to science, there were three articles sent for publication:

First article "Equationless qualitative models of Science Parks Part I, Individual Scenarios as Models Solutions" Journal: Futures,

Second article Equationless qualitative models of Science Parks Part II, Optimisation by Time Sequences of Scenarios. Journal: Futures,

Third article Multi-Objective Optimization of Science Parks Based on Qualitative Equationless Relations. Journal: The Journal of High Technology Management Research

Summary of the current level of the SP model development. The below given description is an integration of the conclusions given in the papers.

An applicable model of a sophisticated problem represents an extremely complex, multidimensional, absolutely unique and vaguely described system. A conventional quantitative model is prohibitively inaccurate and its results and consequently any conclusions based on them could be misleading.

At present, most of the techniques employed for the analysis of a broad spectrum of problems possess analytical and/or statistical natures. Unfortunately these precise mathematical tools do not always contribute as much as is expected towards a full understanding of tasks under study.

It is no paradox, that less information intensive methods of analysis often achieve more realistic results in cases, where the system which is being modeled is very complex, and/or ill known [30]. Modern computers are extremely powerful tools, but their contribution to solving vague problems from finance and investment using common sense has been practically very small.

Therefore a qualitative trend analysis are used to generate a set of all possible time scenarios [44] . Even very uncertain knowledge is valuable. It is the effectiveness with which uncertain knowledge is used, which is very often the main distinction between good and bad models.

Equationless knowledge is such knowledge, that cannot be formalized by equations because of:

- vagueness
- complexity
- transparency of the final results i.e. inability of the final users (top managers) to understand conclusions based on sophisticated mathematical/logical theories.

There are two basic types of knowledge items, namely deep and shallow. Deep knowledge is knowledge, that represents the basic laws of nature. Roughly speaking a deep knowledge item is such item, which is accepted without any questions by the corresponding professional community. The key deep knowledge item in engineering is the law of mass and energy conservation. Unfortunately there are no deep knowledge items in economics and finance. Any knowledge item has its exceptions and simplifications. Moreover there are different specific interpretations by different experts. [24].

The shallow knowledge item is not related to any deep knowledge item. All sorts of statistical analysis are used to generate shallow models. However, the mathematical forms of these knowledge items, usually mathematical models (e.g. exponential, polynomial) are dictated not by reasoning or by the very nature of the problem under study, but by the statistical theories and, quite often, by tradition and rigid applications of statistical packages. [24].

A semi-deep knowledge item represents such information, which is generally known and rather frequently used, but not generally accepted. The model is represented by an equation and this equation may be used for forecasting purposes [24].

5.4.2 Practical contribution of this research:

This dissertation project result in creation of SP methodology based on qualitative SP modelling using just verbal descriptions, which is tested and ready for the use by real Science Parks decision makers.

Programmed SP algorithms based on qualitative modelling and SP methodology of vague analysis will be used to optimize vague, inconsistent and sparse data and will support decision makers in decision making process. This dissertation makes the crucial step towards the final solution and the reconciliation of all relevant data about SP and will help the decision-makers to make correct (optimal) decisions.

6. Conclusion

SPs are typical examples of problems, which are of interdisciplinary nature and unique. The main consequence is, that it is prohibitively difficult to develop a relevant quantitative models. It is possible to develop a qualitative SP model using just verbal descriptions. Naturally if qualitative information items are used as the only information input in to a model, then the results are exclusively qualitative ones.

A methodology of vague SP modelling is built up and the basic philosophy can be summarized in the following heuristics:

- SPs knowledge must not be modified to fit the network of available calculi, but the calculi must be so flexible, that they can formalize vague and inconsistent knowledge with the minimum amount of modifications or simplifications of the knowledge.
- The network of calculi must be capable of reasoning based on sparse knowledge and must be at least partially capable of performing not just numerical calculations, but of making logical deductions as well.
- A SP model has to be developed on a ad hoc basis.

Any qualitative unsteady state behaviour of a SP is always represented by a path in the transitional graph. This fact allows us to identify, for example:

- a suspicious behaviour of the process, probably a failure
- a shallow quantitative model can be used as a sub algorithm of a decision making support
- behaviours of such variables, that are either not measurable or are not measured

A qualitative reasoning/models are probably promising methods. The main advantages of a qualitative analysis are that:

- No numerical values of constants and parameters are needed and the set of qualitative solutions is a superset of all meaningful solutions.
- Complete list of all futures/histories is obtained.
- Results are easy to understand without knowledge of sophisticated mathematical tools.
- The set of solutions (analysis scenarios) is probably complete i.e. there cannot be any other qualitative scenarios, that are not generated by the qualitative model.

However, real life problems often involve data which are vague, inconsistent and sparse. The crucial step towards the final solution is the reconciliation of all relevant data [33]. Human thought is not based on equations and the most powerful tool used by human beings to solve real problems is common sense reasoning [44]. A qualitative model is the best available calculus, which can be used as a theoretical background to formalize common sense reasoning.

All objectives (main objective and sub-objective) in the dissertation have been properly met. Therefore we can say that the work contains everything what was determined.

7. Literature

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9. List of abbreviations

BES	Benefit of economies of scale
BP	Bargaining power
CIA	Cooperation between industries and academics
CII	Circulation of industry information
CIP	Competitiveness and Innovation Programme
CR	Czech Republic
CS	Competition status
CSC	Completion of supply chain
ETP/ETPs	European Technology Platforms
EU	European Union
FP7	7 Research Framework Programme
HBC	Human brain cultivation organizations
HR	Human Resources
HRST	Human resources in science and technology
IC	Innovative centers
IE	Investment, Environment
II	Incentives for investment
INMS	Ill-known, nonlinear, multidimensional system
IPC	Innovative potential of companies
IR	Incubator Resources
LU	Living Utilities
MD	Market Development
NACE	Nomenclature générale des Activités économiques dans les Communautés Européennes (Classification of Economic Activities)
NJC	New job creation
NTP	National Technology Platforms
OC	Operation costs
OCE	Occasion for enterprises cooperating
OECD	Organisation for Economic Co-operation and Development
PI	Prospects of industries
QBE	Quality of business environment
QE	Quality of enterprises
QRD	Quality of R&D engineers
QRI	Quality of research institutions
R&D	Research and Development
R&D Personnel	Research and development personnel
RAIC	Regional Advisory and Information Center
RDA	Regional Development Agencies
RDO	Regional Development Outlook
RE	Reputation
RIS	Regional Innovation System
S&E Professionals	Science and Engineering Professionals
S&T	science and technology
SF	Structural Funds
SI	Scale of industries
SME/SMEs	(Micro) Small and Medium Enterprises
SP	Science Park
SQP	Supply of qualified outside personnel
SRA	Strategic Research Agenda
TR	Technological Resource
UHR	Use of human resources

10. List of Tables

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12. Attachments

Energy	ICT	Bio-based economy	Production and processes	Transport
Biofuels	ARTEMIS	FABRE TP	ECTP	ACARE
SmartGrids	ENIAC	Food	ESTEP	ERRAC
TPWind	ISI	GAH	ETP SMR	ERTRAC
Photovoltaics	Net!Works	NanoMedicine	Manufuture	Waterborne
ZEP	NEM	Plants	FTC	ESTP
SNETP	NESSI	Forestry	WSSTP	
RHC	EUROP		SusChem	
	EPoSS		EuMaT	
	Photonics21		IndustrialSafety	

Fig. 22 - Individual ETPs [80]

National Technology Platforms are linked to the European Technology Platforms (ETPs), which are active on European level [75]

Table 8 - National Technology Platforms [75]

Number	Platform name	Focus of activity
1.	Czech Technology Platform for use of bio components in transportation and chemical industries, (Biosložky)	Solving technology and problems of biofuel of II generation, ie produced from non-food renewable sources, focusing on: • biomass resources and their logistics • preprocessing and primary processing of biomass • Secondary processing of biomass and utilization of residues • sustainability, environmental and legislative issues using bio-components
2.	Czech Technology Platform for Sustainable	The aim of the platform is to examine, identify and eliminate potential risk of development

	Chemistry, (SusChem ČR)	of chemistry in three basic areas: industrial biotechnology materials technology and new types of reactions and processes with regard to technological advancement, environmental friendliness, legislativu a surovinovou dostatečnost.
3.	Czech Biogas Association o.s.	Research, development and innovation in the production and use of biogas
4.	Czech Technology Platform on Industrial Safety o.s. (CZ-TPIS)	Support for organizations active in the development of security industry in Czech Republic, a common national interest in identifying the area of industrial safety and uniform enforcement of those interests at European level.
5.	Czech Membrane Platform o.s.	Membranes, membrane processes
6.	Technological platform for IT services	The main object of activity of business of Technology platform for IT services is to create an industry cluster (the technology platform) in IT services as a driver of development in this progressive area of Czech knowledge-based economy. The platform supports the creation of a favorable business environment, IT services and improve conditions for entrepreneurship and innovation.
7.	Technology platform Manufacturing Technology	Manufacturing technology - machine tools with technology of machining and forming
8.	Czech Hydrogen Technology Platform (HYTEP)	Promoting development and use of hydrogen technologies in CR
9.	Interoperability of the railway infrastructure	The activities of TP is to achieve consistent production of associated industrial companies with the requirements of the European railway

		interoperability for critical follow-up production innovation of Czech Railway Industry implicating the function of trans-European rail system.
10.	Czech Technology Platform of Plant Biotechnology - Plants for the Future (ČTP RB)	ČTP RB mission is to act primarily as a platform for exchanging opinions and experience in the field of plant biotechnology. For this purpose, ČTP RB supports basic research, applied research or xperimental development, supports the promotion of results through teaching, publishing or technology transfer; supports organizations working for development of biotechnology in Czech Republic and related scientific, research, technology and innovation activities, including activities aimed at protecting the environment and improving the positive perception of plant biotechnology.
11.	Road Transport Technology Platform	The project aims to link potential manufacturing sector, operators, research, education and design organizations, government representatives, consumers and users in the field of road transport.
12.	National Technology Platform NGV	Use of natural gas and biogas in transport. It is an association of Chemical Technology, Technical University in Prague, Czech Biogas Association, Automotive Industry Association, Motor Jikov Engineering and other companies in the industry.

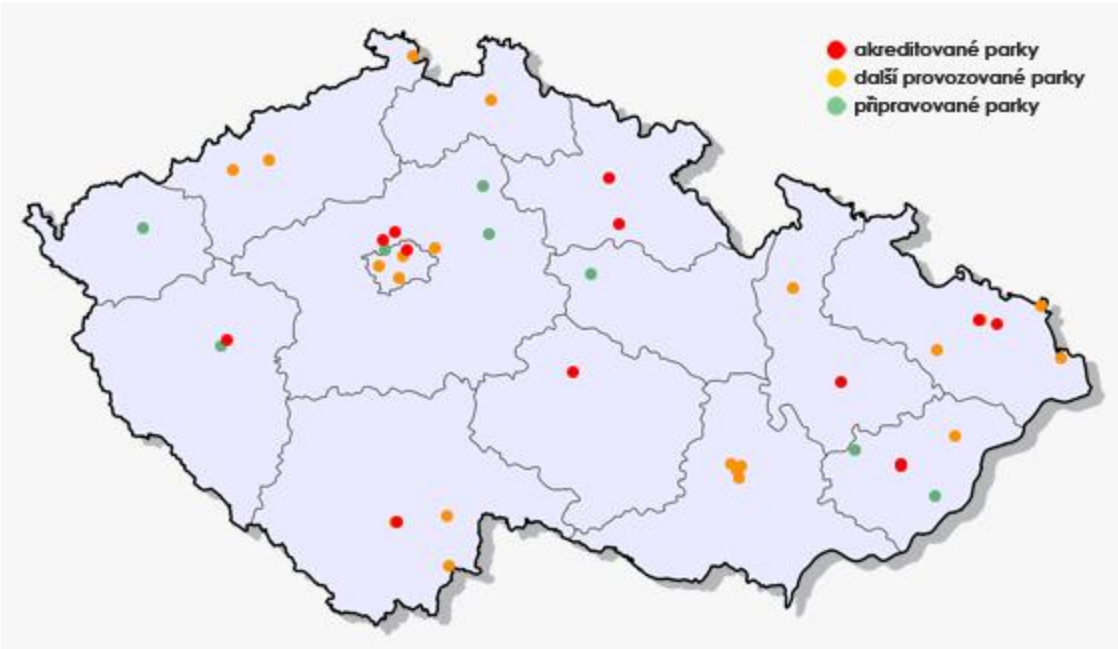

Fig. 23 - Science Parks STPA ČR [95]

Accredited parks:

BIC Ostrava, Ostrava

BIC Plzeň, Plzeň

CTTV – INOTEX, Dvůr Králové n.L.

Inovační technologické centrum – VÚK, Panenské Břežany

Jihočeský vědeckotechnický park ČB, České Budějovice

Podnikatelský a inovační park H. Brod, Havlíčkův Brod

TECHNOLOGICKÉ CENTRUM Hradec Králové, Hradec Králové

Technologické inovační centrum, Zlín

Vědecko – technologický park Ostrava, Ostrava

Vědecko technický park Řež, Husinec – Řež

Vědeckotechnický park při UTB ve Zlíně, Zlín

Vědeckotechnický park UP v Olomouci, Olomouc
Vědeckotechnický park VZLÚ Praha, Praha – Letňany
VYRTYCH – Technologický park a inkubátor, Březno

Other operated parks:

Akademické a univerzitní centrum, Nové Hrady
BIC Brno, Brno
Inovační biomedicínské centrum ÚEM AV ČR, Praha
Podnikatelské a inovační centrum Most, Most
Podnikatelské centrum RUMBURK, VTP, Rumburk
Podnikatelský a inovační park Agritec, Šumperk
Podnikatelský inkubátor Brno – Jih, Brno
Podnikatelský inkubátor RVP Invest, Fulnek
Podnikatelský inkubátor STEEL IT, Třinec
Podnikatelský inkubátor Vsetín, Vsetín
Podnikatelský inkubátor VŠB-TU Ostrava, Ostrava-Poruba
Středisko rozvoje IT OLLI, Brno
Technologicé inovační centrum ČKD Praha, Praha 9
Technologický inkubátor VUT a TI2 v Brně, Brno
Technologický park Chomutov o.p.s., Chomutov
Technologický park při VÚTS Liberec, Liberec
TIC ČVUT Praha, Praha 5
Třeboňské inovační centrum (TIC), Třeboň
Vědecko technologický park Dakol, Petrovice u Karviné
Vedecko-technologický park Žilina, Žilina
Vědeckotechnický park Agrien, České Budějovice
VTP Mstětice, Zeleneč – Mstětice

Upcoming Parks:

6th RIVER-Plzeňský VTP, Plzeň
BIC Brno, Podnikatel. a inovační centrum, Brno
Centrum aplikovaného výzkumu Dobříš, Dobříš
INBIT, Brno,
Jádro Inovačního centra Olomouc,

Podnikatelské centrum Slavičín, Slavičín
Podnikatelský inkubátor Kroměříž, Kroměříž
Podnikatelský inkubátor Nymburk, p.o., Nymburk
Technologické centrum Akademie věd ČR, Praha 6
Technologický park Karlovy Vary, Karlovy Vary
Vědeckotechnický park JMK, Brno [95]

Business incubators in Czech Republic mostly arise on the initiative of regions or cities or as associated workplaces of universities and colleges. Their operation is partly financed from public money. However, you can also find incubators operating without public support and built on a purely profit-principal. Currently works in Czech Republic tens of these entities.

CzechInvest, which provides Program Prosperity, indicate on its website, these institutions

- South Moravian Innovation Centre (JIC)
- Business Incubator Technology Park of University Palackého in Olomouc
- BIC Ostrava
- Technology and Innovation Centre Zlín
- Academic and University Center Nové Hrady
- Třeboň Innovation Centre
- Sscience and technology park Ostrava
- BIC Pilsen,
- Business and Innovation Centre Northern Bohemia,
- Inovacentrum,
- Technology Centre Hradec Králové,
- Technology Innovation Centre ČKD Praha. [88]

Table 9 - Researchers: by region, 2009 [71]

CR, regions	Total	Women	By main sector of their employment					
			Business enterprise sector		Government sector		Higher education sector	
			Total	Women	Total	Women	Total	Women
Czech Republic	**28 759**	**7 490**	**12 657**	**1 898**	**6 270**	**2 316**	**9 664**	**3 212**
Prague	12 076	3 701	3 106	510	4 503	1 753	4 363	1 392
Middle Bohemia	2 889	570	2 399	421	483	145	7	4
South-Bohemia	868	254	246	40	260	80	331	123
Pilsen	886	139	572	41	30	12	284	86
Karlovy Vary	62	15	59	15	2	0	1	-
Ústí	370	114	200	54	29	12	141	49
Liberec	502	86	315	45	9	3	171	34
Hradec Králové	804	206	560	98	47	25	197	83
Pardubice	1 142	184	874	113	52	10	216	60
Vysočina	358	47	343	43	13	3	0	0
South-Moravia	5 136	1 297	2 145	285	753	243	2 224	766
Olomouc	1 016	254	485	64	8	4	514	187
Zlín	816	138	666	88	6	4	145	47
Moravian-Silesian	1 835	485	687	83	75	20	1 073	382

Table 10 - Key R&D indicators [72]

Indicator	2005	2006	2007	2008	2009
Number of businesses engaged					
in R&D, total	**1 855**	**1 966**	**2 022**	**2 047**	**2 155**
Number of businesses with R&D					
as principal activity (CZ-NACE 72)	299	245	228	217	216
Total R&D personnel					
(31 December; headcount)	**65 379**	**69 162**	**73 081**	**74 508**	**75 788**
By occupation:					
Researchers	37 542	39 676	42 538	44 240	43 092
Technicians	19 652	21 338	21 644	21 516	23 285
Other supporting staff	8 185	8 147	8 898	8 751	9 411
Gross domestic expenditure on R&D (GERD), total (CZK mil.)	**42 198**	**49 900**	**54 284**	**54 108**	**55 350**
Current R&D expenditure	37 369	40 692	47 100	48 154	49 762
Wages and salaries	15 499	17 199	20 287	21 895	22 846
Capital expenditure	4 829	9 208	7 184	5 954	5 588
By source of funds:					
Business enterprise	22 825	28 399	29 290	28 242	25 367
General government	17 248	19 445	22 362	22 342	24 301
Funds from abroad	1 669	1 529	2 209	2 893	5 070
Other national	456	528	423	631	612
By type of R&D activity:					
Basic research	11 952	14 630	16 152	16 288	16 918
Applied research	11 123	12 011	13 803	14 350	13 310
Experimental development	19 123	23 259	24 329	23 470	25 122

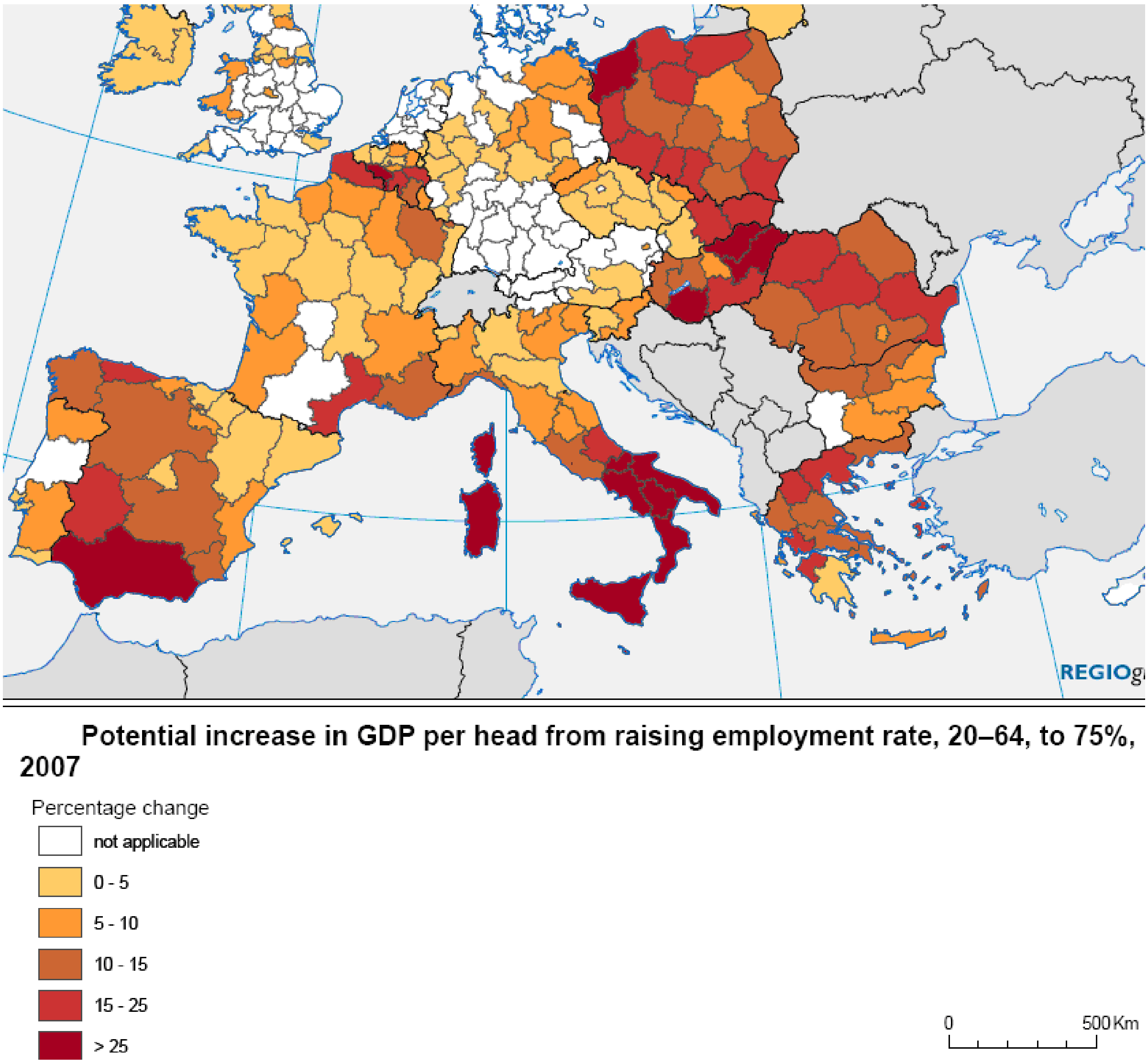

Fig. 24 – Potential increase in GDP per head from raising employment rate, 20-64, to 75%, 2007 [81]

Fig 24 shows the increase in productivity growth within sectors. It shows that in most regions in the EU-12, the increase has been significant, reflecting the introduction of more technically advanced and more efficient production and organisation. [81]

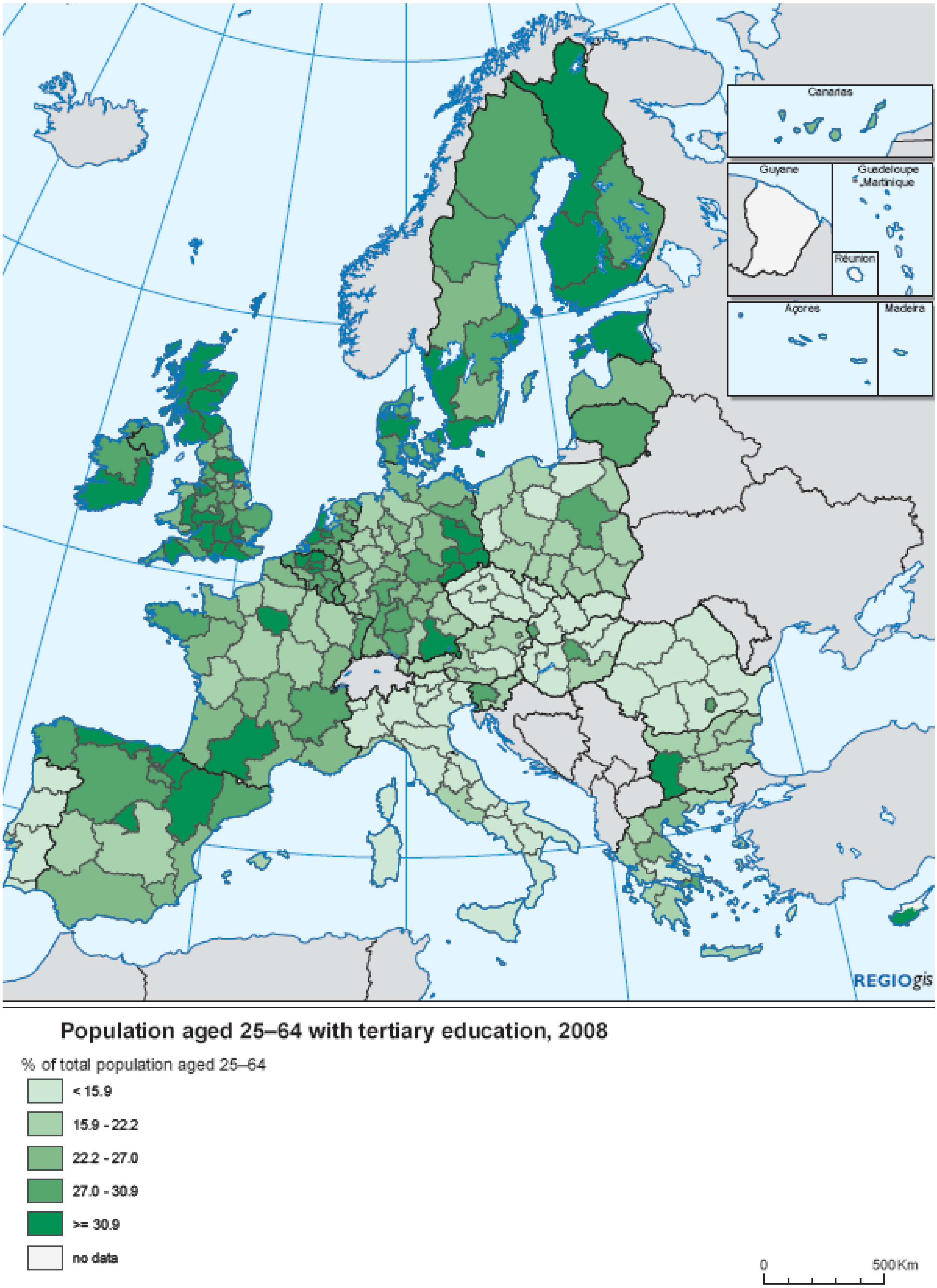

Fig. 25 – Population aged 25-64 with tertiary education, 2008 [81]

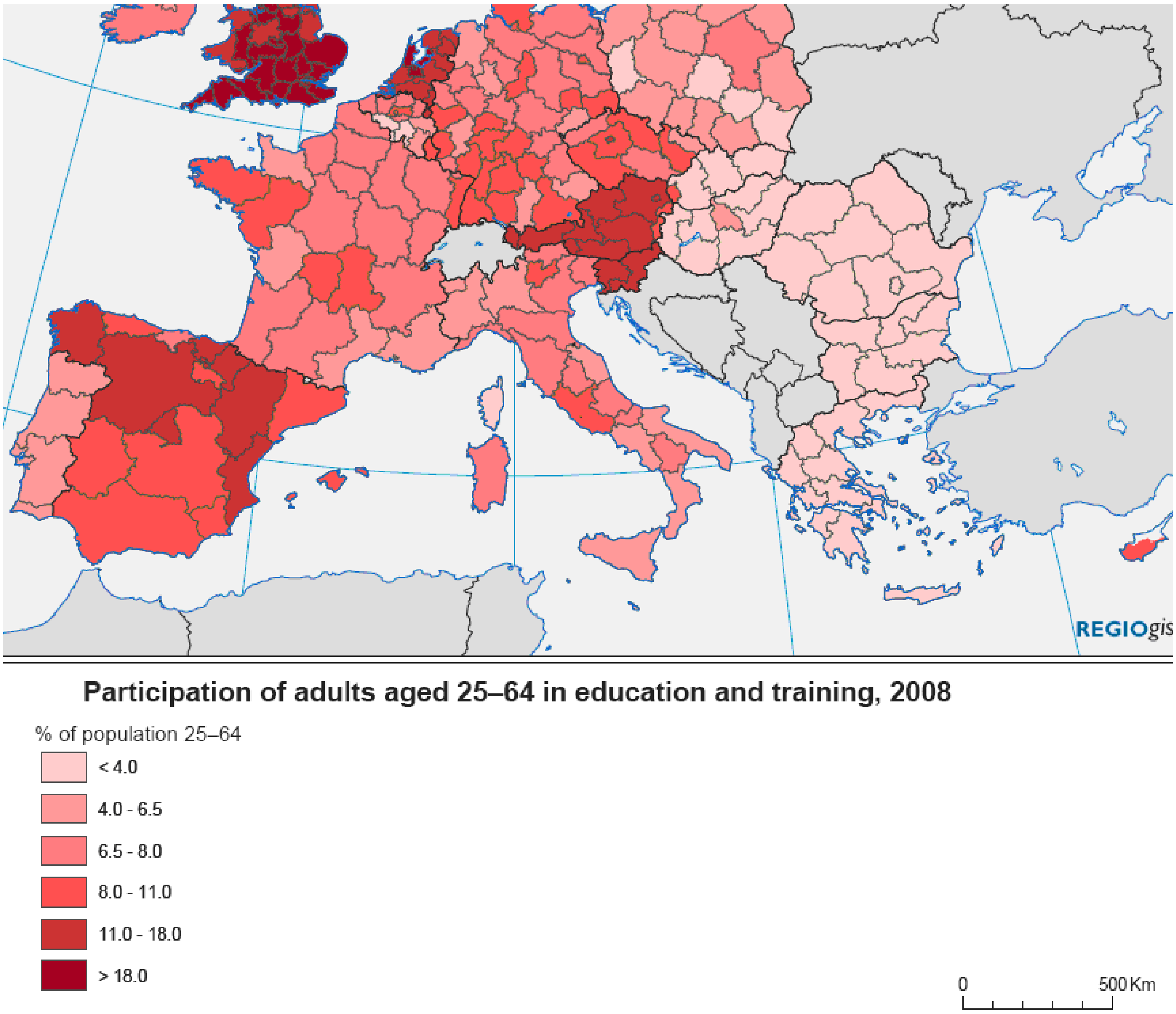

Fig. 26 – Participation of adults aged 25-64 in education and training, 2008 [81]

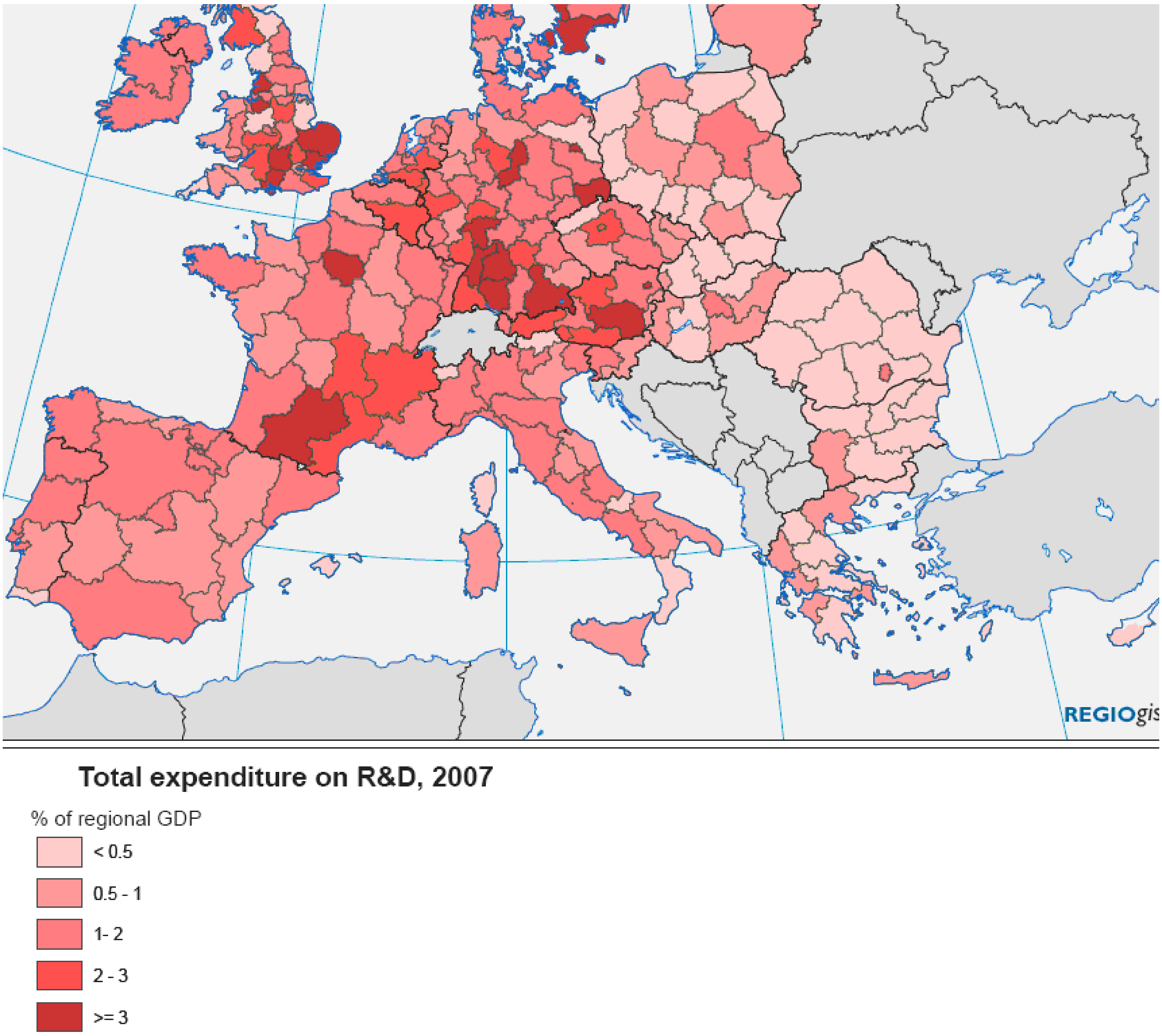

Fig. 27 – Total expenditure on R&D, 2007 [81]

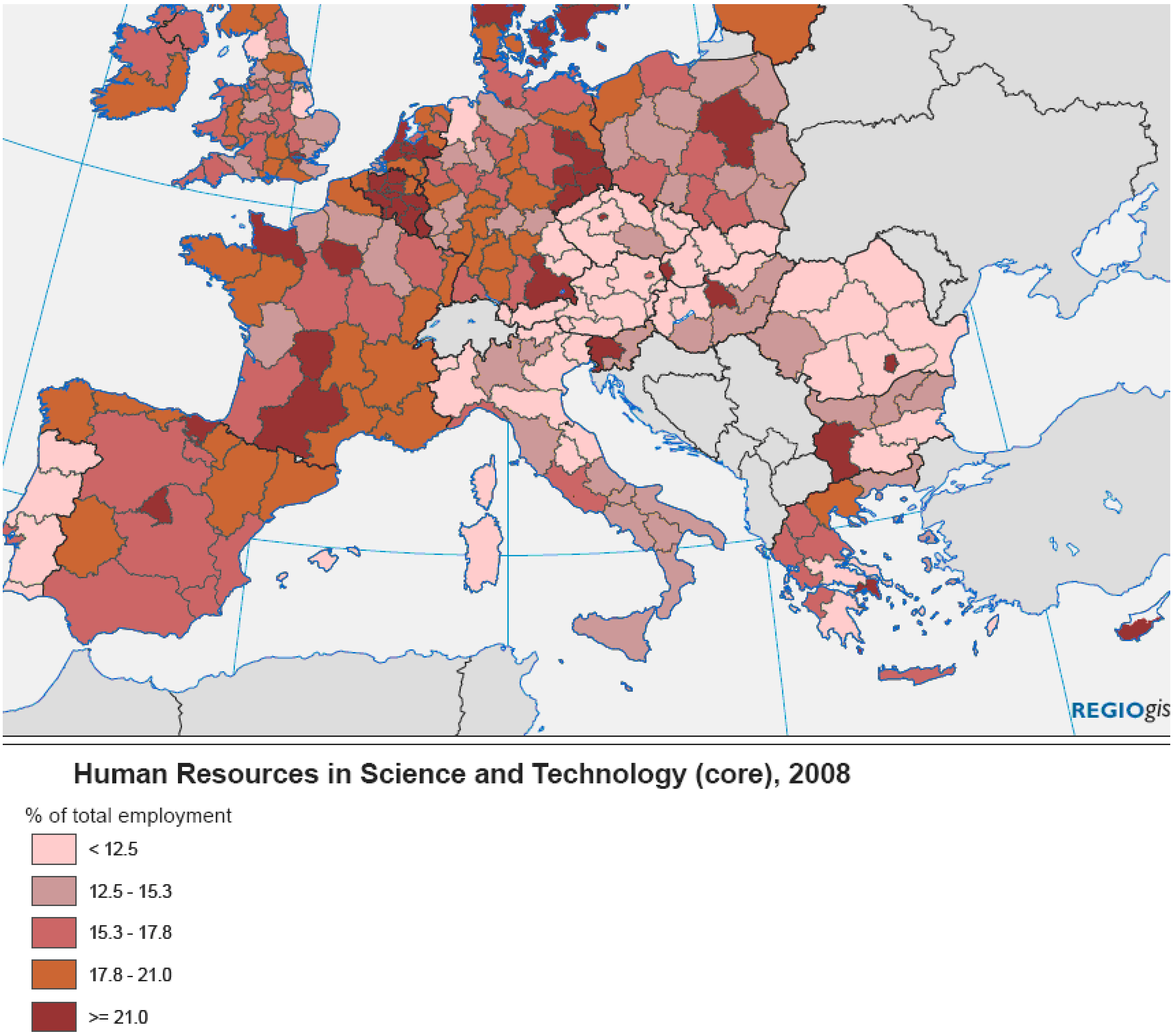

Fig. 28 – Human Resources in Science and Technology (core), 2008 [81]

Regional disparities in this regard are equally wide. In 2008, HRSTC was 30% or above in Brabant Wallon in Belgium, Stockholm, Inner London and Berlin. It was less than 8% in Corse, Sud-Muntenia in Romania, Açores in Portugal and Severozapad in Bulgaria (Fig. 27). Again, regions highly endowed with an educated workforce generally have higher levels of GDP per head and are often capital city regions. Only 4 out of the top 20 regions in terms of HRSTC have a GDP per head below the EU average and 12 are capital city regions. [81]

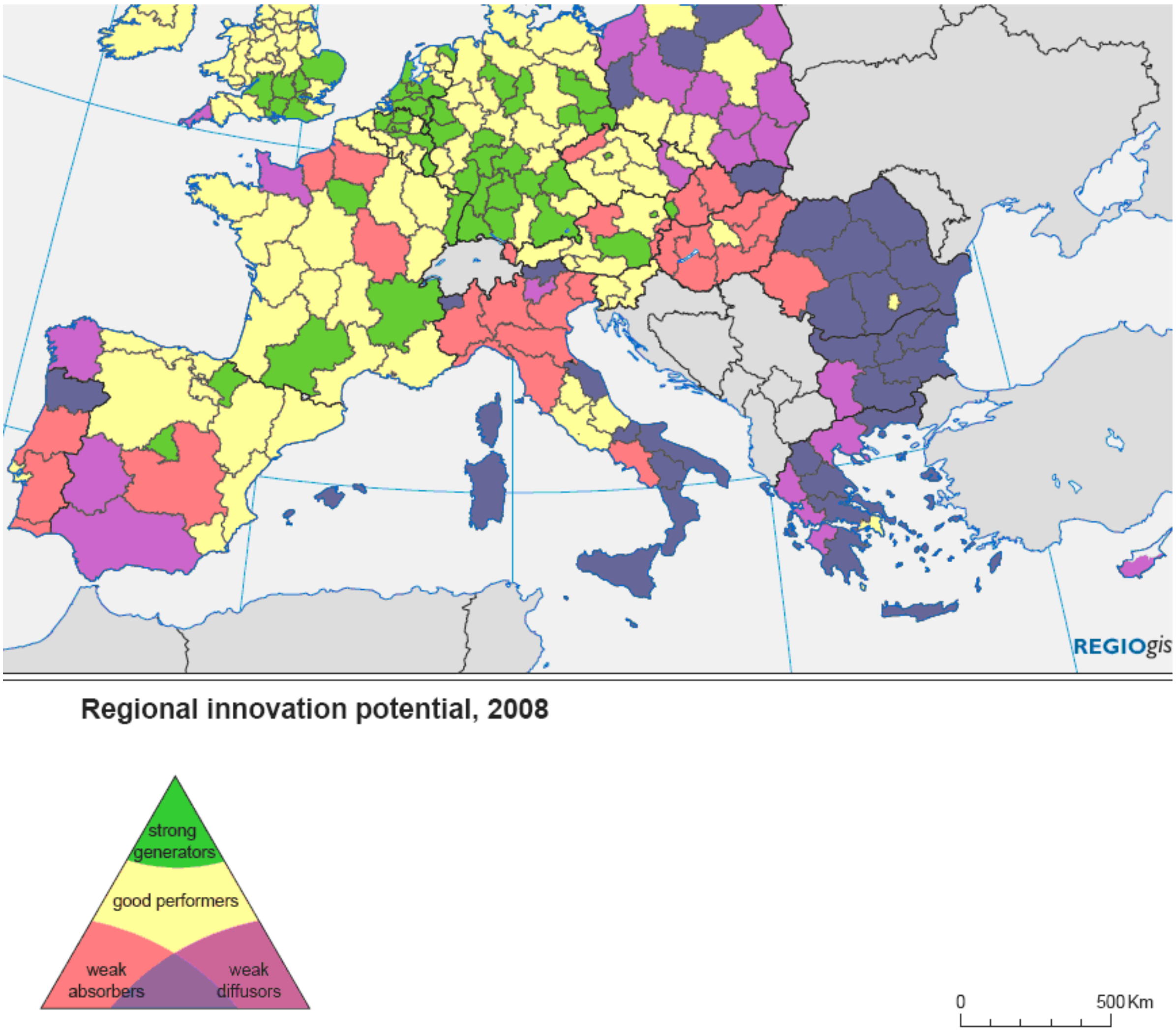

Fig. 29 - Human Resources in Science and Technology (core), 2008